Texts and Tasks in Elementary Project-Based Science

by

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DEDICATION

I dedicate this dissertation to the teacher and her class of third-graders who welcomed me into their classroom for this study. I was honored to be a part of your *Multiple Literacies in Project-based Learning* experience. Thank you for sharing it with me.

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ABSTRACT

Standards-based reforms in K-12 literacy and disciplinary education call for engaging students in meaningful uses of literacy tools of reading, writing, and oral language in service of participating in disciplinary practices and building disciplinary knowledge. Despite calls for educational reform and the introduction of new academic standards, such as the Common Core State Standards (CCSSO, 2010) and the Next Generation Science Standards (NGSS Lead States, 2013), too few K-12 classrooms have meaningfully taken up these ideas in curriculum and instruction. For example, literacy instruction has long been divorced from knowledge building. Further, limited instructional time for disciplinary instruction in elementary classrooms poses challenges to achieving the objectives outlined in rigorous standards-based reforms. One approach to addressing these problems is the thoughtful integration of literacy and science instruction in the elementary grades. In this dissertation study, I investigated the design and enactment of texts and tasks in an elementary project-based science curriculum. The following research questions guided this study: (1) How do texts and related tasks, designed for – and enacted in – project-based science instruction, support or constrain third-graders' knowledge building and development of foundational and disciplinary literacies? (2) How might modifications to texts and tasks within the designed curriculum better support third-graders' knowledge building and literacy development?

This study took place in one third-grade classroom with 31 students and their teacher across a full year of project-based science instruction. The focal curriculum, Multiple Literacies in Project-based Learning (MLs), integrates science, English language arts, and mathematics, and addresses the three-dimensional learning goals of the NGSS and select CCSS. Within and across MLs units, students had multiple opportunities to read and interpret a variety of traditional print, multimodal, and digital texts. The teacher was an experienced elementary school teacher and a second-year participant in the MLs project.

I used design-based research (Brown, 1992; Collins, 1992) and case study methods (Stake, 1995) to investigate the design, enactment, and improvement of focal texts and tasks. I used conjecture mapping (Sandoval, 2014) to identify salient and theoretically compelling features of the design of the instructional intervention, focused on literacy integration, and to map how features of the designed curriculum and the teacher's enactment worked together to produce specific outcomes. Data sources for this study included field notes and videos of classroom observations, interviews with focal students and their teacher, artifacts, and the designed curriculum materials. Focal students were selected to represent a range of reading achievement and to reflect the demographics of the class.

Findings indicated that: (a) the pairing of texts and tasks in the context of project-based science instruction created meaningful purposes for students to read and interpret multimodal informational texts; (b) the design and enactment of texts and tasks engaged students in using text *in service of* disciplinary knowledge-building and practice, creating opportunities for – and supporting – students' science and literacy learning; and (c) texts served as tools for creating and sustaining coherence in PBL. I also identified missed opportunities within the design and enactment of the curriculum, which may have constrained students' opportunities to learn in the context of project-based science instruction. These findings can inform revisions to the design of the MLs curriculum, and have implications for future curriculum design, the availability and use of informational text in elementary-grade classrooms, and educational policy.

CHAPTER I: INTRODUCTION

Recent calls for reform in literacy and disciplinary education emphasize meaningful uses of literacy tools of reading, writing, and oral language, as well as meaningful engagement in disciplinary practices, each in service of disciplinary knowledge building. While these calls are not new (e.g., Hirsch, 2003, 2006), they have been reinvigorated in recent years. As such, they have ushered in comprehensive standards-based reforms in K-12 education, such as the Common Core States Standards for English language arts (CCSSO, 2010), focused on literacy education; and the Next Generation Science Standards (NGSS Lead States, 2013), focused on science and engineering education.

To illustrate, decades of reading research have pointed to the synergistic relationship between knowledge building and reading comprehension. Reflecting this stance, the Common Core State Standards in ELA emphasize disciplinary knowledge building as a goal of literacy instruction. In the domain of science, the NRC Framework (2012) outlined a vision for standards-based reform in science education that articulated the power of pairing knowledge-building about core ideas in science with engaging in scientific and engineering practices across K-12 grades. This vision was then instantiated in the NGSS, which outlines three-dimensional instructional goals integrating disciplinary core ideas, scientific and engineering practices, and crosscutting concepts.

Despite the calls for educational reform and the introduction of new standards that reflect these calls, too few classrooms and schools have meaningfully taken up these ideas in curriculum materials and instruction. For instance, literacy instruction has long been and, too often continues to be, divorced from knowledge building. This may be particularly true in the elementary grades, where a genre imbalance favoring narrative over informational text has been documented by observational research (e.g., Brenner, Hiebert, & Tompkins, 2009; Duke, 2000; Jeong, Gaffney, & Choi, 2010). Thus, the field needs to identify additional sources of informational – disciplinary – text for students in the elementary grades, as well as meaningful instructional tasks that call for their use.

The current state of affairs in elementary science instruction is equally problematic, in part due to the limited time that is allocated to science instruction in the United States, particularly in the early grades. According to teacher surveys from the National Assessment of Educational Progress (NAEP) 2015 science assessment, students in the elementary grades spend an average of only thirty-minutes per day on science instruction – a total of approximately three hours in a typical school week (NCES, 2016). For many elementary-grades students, opportunities to engage in science instruction are even fewer: over twenty percent of fourth-grade teachers reported dedicating fewer than two hours per week to science instruction. This is not enough time to meet the rigorous objectives outlined in standards-based reforms, such as NGSS, which call for deep learning and engagement in science instruction that integrates core ideas, scientific practices, crosscutting concepts.

One approach to addressing these problems is the thoughtful integration of literacy and science instruction in the elementary grades. A natural synergy between literacy and science, identified in the National Research Council's (2014) Literacy for Science Workshop Summary, is that learning science can provide meaningful purposes for reading and writing in the classroom. In other words, weaving together literacy and science can create meaningful contexts for students to develop literacy tools in support of knowledge-building and engaging in first-hand experiences. While previous research on the use of text in elementary science provides some examples of the types of texts and instructional activities that support knowledge building and literacy development (e.g., Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012; Guthrie et al., 2009; Palincsar & Magnusson, 2001; Romance & Vitale, 2001), we need to better understand the ways in which texts might be designed and enacted in the context of reform-oriented literacy and science instruction in service of students' knowledge building, literacy development, and engagement in scientific practice.

In this dissertation study, I investigated the design and enactment of texts and tasks, in the context of elementary-grades Project-based learning (PBL). Within this instructional context, I looked closely at how the designed texts and tasks were taken up by one third-grade teacher and her students, and the ways in which the designed curriculum created opportunities for and supported students' science and literacy learning across one year of project-based science instruction.

Research Questions

In this design-based (Brown, 1992; Collins, 1992) and case study research (Stake, 1995), which was conducted in the context of project-based science instruction, I posed the following research questions:

1. How do texts and related tasks, designed for – and enacted in – project-based science instruction, support or constrain third-graders' (diverse with respect to academic achievement) knowledge building and development of foundational and disciplinary literacies?
2. How might modifications to texts and tasks, within the designed curriculum, better support third-graders' knowledge building and literacy development?

Instructional Context of the Study

The instructional context in which I conducted this dissertation study is *Using Multiple Literacies in Project-based Learning*[1] (MLs). The MLs project is a cross-institution collaboration with the aim of developing iteratively designed, integrated project-based science, literacy, and math curricula for the elementary grades, which address the three dimensions of the Next Generation Science Standards (2013) and select Common Core State Standards for English language arts and mathematics (2010). Project-based science instruction is characterized by the following features: (1) use of a "driving question" that is meaningful to students and anchored in real-world problems; (2) student participation in hands-on investigations and creation of artifacts in pursuit of the driving question; (3) collaboration among students, teachers, and others in the community; and (4) use of cognitive tools, such as digital technologies, to scaffold learning, inquiry, and collaboration (e.g., Marx et al., 1994). The MLs curriculum adds the use of literacy tools of reading, writing, speaking, and listening, in service of building knowledge and engaging in scientific practices, to these design features. Thus, within and across MLs units of instruction, students have multiple opportunities to read and interpret a variety of traditional print, multimodal, and digital texts as they engage in PBL.

The MLs approach to literacy and science integration, in the context of project-based science instruction, braids reading, writing, and oral language to first-hand science investigation and inquiry in service of students' engagement in scientific practices and knowledge-building. At the same time, first-hand science investigations and inquiry provide meaningful contexts and

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purposes for students to read, interpret, and write informational text. Thus, while the MLs curriculum foregrounds three-dimensional science learning goals, outlined in the NGSS, we also recognize that those goals cannot be attained without literacy tools of reading, writing, and speaking. In addition, we explicitly target select literacy learning goals outlined in the CCSS ELA standards. Finally, we also hypothesize that the integration text may play important roles in creating and sustaining coherence in PBL instructional units, in which students engage in inquiry and artifact development in pursuit of answering a driving question.

Building on previous research investigating the integration of text and experience in the context of science instruction (e.g., Cervetti & Barber, 2008; Palincsar & Magnusson, 2001), the MLs curriculum design team hypothesizes and designs a number of important roles for text in project-based science instruction, such as: (a) provide context for, support, and extend first-hand investigations; (b) introduce and illustrate core ideas by inviting students to think about their everyday experiences in a new way, sharing aspects of the natural world that are unlikely to be familiar to elementary students, providing information that cannot be observed in classroom contexts, and introducing the natural contexts in which scientific phenomena unfold; (c) establish connections between students' investigations, core ideas, and crosscutting concepts; (d) connect first-hand investigations with the work of professional scientists and engineers; (e) introduce and illustrate scientific and engineering practices; (f) supplement evidence that students' create first-hand; (g) provide opportunities to analyze and interpret data.

Research Methods and Design

I designed and conducted this dissertation study within a larger design-based research (DBR) project (Brown, 1992; Collins, 1992) focused on the design, evaluation, and improvement of an intervention as it interacts with the contextual variables integral to enactment (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004). In this dissertation study, I use DBR and case study methods (Stake, 1995) to examine the design, enactment, and improvement of texts and tasks designed for use in an elementary project-based learning intervention, which integrates science, English language, arts, and mathematics. Specifically, I investigated how texts and literacy tasks designed for elementary project-based science instruction supported, or constrained, the knowledge building and literacy development of students, with diverse literacy achievement profiles, in one third grade classroom.

I used conjecture mapping (Sandoval, 2014), a systematic approach to DBR, in order to identify theoretically salient features of the design of the instructional intervention related to literacy integration. I focus specifically on the design of texts and text-related tasks integrated within the curriculum, and map how designed features are predicted to work together to produce specific outcomes. Mapping conjectures guided my data collection, analysis, and case study construction. After introducing the map in Chapter 3, I revisit the map in each findings chapter and use it to introduce the features of the map foregrounded in my analyses and findings related to each focal text and task pairing. Finally, I present and discuss a revised map in Chapter 8.

Organization of the Dissertation

In the next chapter (Chapter 2), I describe the conceptual framework for this dissertation study. I begin the chapter with a vignette of project-based instruction in the focal classroom. I then follow this vignette with a review of pertinent literature and conclude with a discussion of the theoretical perspectives informing this research. In Chapter 3, I describe my study's design and research methods, as well as the instructional context, research context, and participants. In Chapters 4 though 7, I report my findings, which are organized around each of the four third-grade MLs units of instruction. For each unit, I present findings specific to the design and enactment of two focal texts or text sets within the instructional unit. Finally, in Chapter 8, I begin with a discussion of the ways in which the development and revisiting of the conjecture map supported the design and implementation of my study, and informed revisions to the literacy resources and related lessons within the MLs curriculum. Then, I synthesize findings relevant to the design and enactment of the eight focal texts or text sets and describe implications and limitations of the present study. Finally, I close with a discussion of directions for future research.

CHAPTER II: CONCEPTUAL FRAMEWORK

On a bright April afternoon, a third-grade teacher and her students walked to an open area of their school campus to play a "bird migration" game, in which the students, taking on the role of migrating birds, navigated a series of stations. When students stopped at the different stations, they read and responded to a series of prompts, which described – and illustrated with photographs – situations that facilitate migration (e.g., a strong favorable wind, bird houses and feeders) or pose obstacles (e.g., habitat destruction, oil spills, predators) for migrating birds.

The next day, the teacher asked students to report on their experiences and the information they learned while playing the game. Gathered on the carpet in the front of the classroom, the teacher asked, "What was the point of that game?"

"To act like a bird," one student responded.

"Okay, you were acting like a bird, and in terms of acting like a bird, what were you actually doing?"

"Going on a migration, and one of the things (that I learned is) that birds can't see glass so they just run right into glass," another student shared.

"So, that was something new that you learned…Not only were you playing a game, but for many of you, you kind of learned something new about a bird's migration path." As the conversation continued, the teacher invited other students to share obstacles they encountered as they played the game as well: "What are some of those obstacles or difficulties that birds face on their path of migration?" Eager to share their learning, almost every student threw a hand into the air.

"Predators," one student responded.

"If they're a water bird, they might deal with oil spills," another added.

A third student explained that, "Most birds, while they're on their migration path, die because of predators or starvation."

The students and their teacher continued sharing and synthesizing their learning, based on the texts and activity of the game. As the lesson progressed, the teacher introduced an informational text designed to deepen students' learning from the migration game, called *The Whys and Hows of Bird Migration*, and began reading the text aloud as her students followed along. During the interactive read aloud, the teacher paused frequently to engage students in discussing the ideas in the text and to make connections to their prior knowledge and experiences from the unit of instruction and students' lives.

The teacher read one of the headings in the text aloud, "How do birds know when it is time to migrate?" Before reading this section of the text, she posed this question to the class.

One student answered, "The weather change…hotness."

"Okay, so the change in temperature." The teacher continued reading, "There are several clues that birds use to know when it's time to migrate. What are some changes that we experience in the fall?"

Another student responded, "Change in ecosystems."

"The ecosystem starts to change. What specifically starts to change in our ecosystem…how would we know that fall was approaching or that we were in the midst of fall?"

"Leaves," one student responded.

Another added that, "The leaves start changing colors and falling off the trees."

"What happens to the length of our days?"

Multiple students responded, “They get shorter.”

The teacher continued to read, “Birds, too, notice that the days are getting shorter and that there is less daylight for them to find food. They notice that it is getting colder. They also notice that there are not as many sources of food, such as insects and berries. These are all clues from the environment that it is time for a change.”

In the course of the interactive read aloud, the teacher linked to an animated map illustrating the migration paths of multiple species of birds. As she projected the map, the teacher asked the students what they were seeing.

“Birds. We’re watching birds migrate,” shared one student.

“Okay, we’re watching the migration of birds…Anything more specific than that?”

Another student added, “We’re watching birds’, from North American, migration path.”

“…So, we’re watching birds of North America and their migration path. What else does this tell us? Anything else…?” the teacher prompted.

A student added, “I see that there’s one bird that’s like staying in the corner over there.”

“Okay, so let me ask you this. You bring up a really good question for me. Do you think each of these little circles represents one bird?” The class agreed that each dot represented a whole species of bird. As the discussion progressed, the teacher and the students continued to read and interpret the information in the dynamic map, and then resumed reading and discussing the ideas introduced within the informational text. The teacher frequently paused to make connections back to the bird migration game, to students’ prior knowledge, and to other unit experiences in order to build knowledge together about bird migration, supported by a variety of texts.

This vignette is taken from data collected for this dissertation study. It illustrates characteristics of curriculum materials and instruction that are at the heart of my study: teachers and students interacting with one another, in the context of project-based learning, supported by a broad array of text sources for the purposes of collectively building knowledge and engaging in inquiry.

In my review of the literature, I situate this study in contemporary standards-based reforms in literacy and science education. I then take up the question of the challenges and possibilities of learning with text in the context of reform-oriented instruction, exploring what we currently know about young children's access to, knowledge building, and inquiry with informational text, particularly in the context of science instruction. I then describe what is not yet known about the design and enactment of reform-oriented instruction that integrates science and literacy, and the ways in which this dissertation study addresses these issues. I conclude this chapter with a discussion of the theoretical perspectives informing this research.

Calls for Reform in Literacy Instruction: Roles of Knowledge Building and Informational Text

Decades of reading research have pointed to the synergistic relationship between knowledge building and comprehension (Cervetti & Hiebert, 2015). In Pearson's (2006) words, "Knowledge begets comprehension begets knowledge." Reflecting this stance, the Common Core State Standards in ELA emphasize knowledge building as a goal of literacy instruction. A corollary of this call is an emphasis on increasing the proportion of informational text that students read and write in the context of literacy instruction, particularly in the elementary grades.

Despite these calls, observational research suggests that many children in the elementary grades spend little class time actually *reading* text, despite the time that is allocated to literacy instruction (Brenner, Hiebert, & Tompkins, 2009; Jeong et al., 2010). In fact, Brenner et al. (2009) sampled 64 third-grade classrooms and found that nearly one-fourth of the third graders did not read at all during observed reading blocks. Brenner et al. (2009) also found that informational text accounted for only 24 percent of reading time in the third-grade classrooms observed; a finding supported by Jeong et al. (2010) and mirroring Duke's earlier research in first-grade classrooms (2000). These findings are troubling because children's opportunities to read are associated with the development of foundational skills such as fluency, vocabulary, and comprehension. In order to engage in knowledge-building with text, students must have opportunities to engage in sustained reading in the classroom. Furthermore, the amount of time children spend reading is one of the best predictors of reading achievement (Anderson, Wilson, & Fielding, 1988; Guthrie, Schaffer, & Huang, 2001). While *all* children need abundant opportunities to read in order to become proficient readers (Chall, Jacobs, & Baldwin, 1990), having plentiful opportunities to read in school is particularly important for those students who depend upon school for literacy learning (Hiebert, 2014).

In addition to supporting students' development of foundational reading skills, there are other benefits to supporting students to learn with informational text. The majority of texts we read on the Internet, in the workplace, and at home are written to communicate information. Informational texts provide opportunities for students to not only build vocabulary and academic language, but also to answer questions, learn about the world, explore their interests, and engage in disciplinary inquiry (Cervetti, Jaynes, & Hiebert, 2009; Duke & Bennet-Armistead, 2003; McRae & Guthrie, 2009). In short, increasing elementary-grade children's diet of informational text provides opportunities for them to build knowledge about the world in which they live, and also to engage in disciplinary knowledge building in the context of subject-matter learning, a topic to which I turn next.

The role of disciplinary literacy. Concurrent with calls for increased use of informational text in literacy instruction to support comprehension and knowledge building, are calls to engage K-12 students in learning and using disciplinary literacies (e.g., Cervetti & Pearson, 2012; Goldman et al., 2016; Moje, 2008; 2015). Moje (2015) defined disciplinary literacy as "the specialized skills and codes necessary for reading and writing in various disciplines and technical fields" (p. 257) and called for elementary-grades teachers to begin the work of apprenticing students to disciplinary reading, writing, and speaking practices as they engage in disciplinary inquiry.

While some research at the secondary level has begun to explore the potential of disciplinary literacy instruction and the design of learning environments that scaffold students' use of disciplinary texts for disciplinary purposes in the context of studying history (Duhaylongsod, Snow, Selman & Donovan, 2015; Shanahan et al., 2016), literature (Sosa, Hall, Goldman, & Lee, 2016), and science (James, Goldman, Ko, Greenleaf, & Brown, 2014), less is understood about the ways in which young students might be supported to learn and use disciplinary literacies. The curriculum materials and instruction featured in the present study are responsive to calls for supporting knowledge building through the use of text and apprenticing students to use text in service of engaging in disciplinary thinking and practices. Because the design of texts and tasks in the focal curriculum aim to engage students in reading text for disciplinary purposes, this study has the potential to speak to questions about how disciplinary literacy instruction might be designed in the elementary grades, and the ways in which teachers and their students might take up these opportunities.

The role of multimodal literacies. Complementing calls for literacy instruction focused on knowledge building and disciplinary literacies, are calls for students to learn and use multimodal literacies in K-12 contexts. These calls are typically issued in the name of preparing citizens for life and work in the 21st century. In addition to traditional print text, literacy scholars (e.g., Jewitt, 2008; New London Group, 1996) and standards-based reforms, such as the CCSS have called for instruction that builds toward multimodal literacy; that is, the ability to learn from text in which words are used in combination with audio, visual, and spatial modes (Mills, 2010). These calls are rooted in the understanding that people draw on many representational resources to make meaning. Language is only one of these resources (Kress & van Leeuwen, 2001). Furthermore, different modes have different affordances and constraints for communicating information. Because of individuals' access to and use of multiple modes of representation in life and work, it is imperative for K-12 students to learn to interpret and use a variety of modes as they engage in knowledge building and disciplinary inquiry.

Embedded within calls for multimodal literacies, are calls for students to develop and use digital literacies. Certainly, digital tools expand the modes of representation to which people have access (i.e., video, audio, and simulations require the use of digital platforms). Additionally, outside of school contexts, students interact largely with digital text – text that is interactive, nonlinear, and multimodal (Dalton & Palincsar, 2013). Indeed, digital technology is now central to daily life in many homes and in the workplace. Dalton (2012) proposed that the CCSS "assume that being literate means being *digitally* literate" (p. 333), and that to be prepared for the demands of school, life, and work in our technological society, students must be able to analyze both print and non-print texts in old and new forms of media.

The project-based science curriculum, which serves as the instructional context in the present study, features traditional informational texts designed for elementary-grades students, but also includes important roles for multiple modes of representation, such as video, audio, images, simulations, and graphical displays. In addition, the curriculum features designed opportunities for students to interpret and produce multiple modes in digital formats.

Finally, literacy researchers and standards-based reforms have called for students to synthesize multiple sources of information in service of knowledge building, and to make rich connections across texts, both within and across representational forms (CCSS, 2010). Goldman et al. (2016) called attention to the fact that, when readers are engaged in disciplinary inquiry, they must build knowledge about complex phenomena for which no single text source or experience can provide a full account.

As this review suggests, reform movements in language literacy are complex and multi-faceted. They place increasing demands on teachers, teacher educators, and curriculum designers. The current study is designed to inform efforts to: increase young children's access to meaningful uses of informational text, with an eye to supporting disciplinary learning, explore the uses of multi-modal texts, and the activity of synthesizing information across multiple text sources. This research is being conducted in the context of science instruction. Just as the language literacy community has been actively calling for reforms in curriculum and instruction, so also has the science education community. I turn to these calls next.

Calls for Reform in Science Instruction

Concurrent with standards-based reforms in literacy education, the Framework for K-12 Science Education (NRC, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013), have called for three-dimensional K-12 science instruction in the United States. These dimensions include scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. In order to engage students in meaningful science learning, the NRC Framework calls for integrating all three of these dimensions into curriculum materials and instruction.

Integral to the vision for K-12 science instruction expressed in the NRC Framework is the suggestion that students learn disciplinary core ideas in the context of engaging in disciplinary practices: "students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined" (NRC Framework, 2012, p. 218). In other words, the NRC Framework and NGSS call for engaging students, beginning in the earliest grades, in scientific and engineering practices, such as developing and using models; planning and carrying out investigations; analyzing and interpreting data; constructing explanations; and obtaining, evaluating, and communicating information (NGSS Lead States, 2013). Engaging in these practices requires students to use literacy tools of reading, writing, and speaking in order to interpret and synthesize multiple, multimodal science texts in service of disciplinary knowledge building, leading to potential synergies to which I turn next.

Synergies in Calls for Reform in Literacy and Science Education

A natural synergy between literacy and science, identified in the National Research Council's (2014) Literacy for Science Workshop Summary, is that learning science can provide meaningful purposes for reading, writing, and oral language in the classroom. In other words, weaving together literacy and science has the potential to create meaningful contexts for students to develop literacy tools in support of knowledge building. Another key synergy between science and literacy instruction, identified in the Literacy for Science Workshop, is that there are limits to both text- and experience-based approaches to learning science – neither approach alone is as productive as thoughtfully integrating the two (NRC, 2014). These ideas echo Palincsar and Magnusson's (2001) earlier recognition of "the impossibility that children will come to meaningful understandings of the nature of scientific thinking simply through the process of interacting with materials and phenomena," and their suggestion that text has an important role to play in practice-oriented science instruction (p. 152). In the next section of text, I examine these synergies in more detail.

Science is a conceptually rich domain for enhancing literacy. There is a general consensus among literacy researchers of the value of engaging students in meaningful literacy activity – reading and writing conceptually-rich texts for meaningful purposes (Guthrie et al., 2004, 2009; Purcell-Gates, Duke, & Martineau, 2007; Romance & Vitale, 1992, 2001). Lemke (1994) argued, "texts whose only context is an arbitrary curriculum task are inferior as learning contexts to texts…that have a wider social context" (p. 11). Meaningful literacy events, therefore, are those that serve communication purposes in real-world social contexts.

Thus, one synergy between literacy and science instruction is that building science knowledge and engaging in scientific practice provide meaningful purposes for students to read and write in the classroom (NRC, 2014). Integrating science and literacy instruction can provide students with rich content through which to develop and refine literacy tools. In addition to providing rich content, science texts frequently combine multiple modes of information, such as print, images, graphs, diagrams, and charts (Prain & Waldrip, 2006). As Pearson, Moje, and

Greenleaf (2010) suggested, “Science provides a setting in which students are intellectually obligated to make sense of data, draw inferences, construct arguments based on evidence, infer word meanings, and, of course, construct meanings from text” (p. 460). Indeed, science texts are particularly well-suited to providing opportunities for students to use reading, writing, and oral language to build and communicate knowledge about the world (Hapgood & Palincsar, 2006/2007).

Reading and writing are tools for practice-oriented science instruction. The NGSS call for students to engage in *doing* science involves the “three-dimensional learning” of scientific practices, core ideas, and crosscutting concepts. In the NRC (2014) Literacy for Science Workshop, Moje argued that teaching language and literacy in the context of science means that students must engage in scientific practices, such as planning and carrying out investigations, analyzing and interpreting data, and constructing explanations, all within the context of engaging in scientific inquiry. Similarly, Pearson (NRC, 2014) argued that science text should be used as a “catalyst for engaging in science practices,” emphasizing that reading disciplinary texts for disciplinary purposes necessarily moves beyond using text merely as a means to deliver science content (p. 13).

Despite long-standing concerns from some science educators that the integration of text and reading into science instruction may supplant or overshadow science inquiry, science and literacy educators largely agree that engaging in science practices requires literacy tools of reading, writing, and oral language (Pearson et al., 2010). As Pearson et al. (2010) noted, “Texts are the artifacts of those past investigations and are used for inductive reasoning about scientific phenomena. Scientists use texts to generate new research questions and to provide the background necessary for research design and investigation” (p. 460). In other words, literacy tools are essential for communicating in science, and scientists use tools of reading and writing to engage in disciplinary practices. Despite this recognition, there is lingering controversy around what constitutes practice-oriented science instruction and the productive roles that text might play in these contexts (Cervetti & Barber, 2008). The current study is designed to inform this problem space by investigating a year-long curriculum in which an elementary teacher and her students were using an array of texts and literacy activities in the pursuit of the three-dimensional goals of the Next Generation Science Standards, as well as select Common Core State Standards for English language arts.

Challenges to Integrating Science and Literacy

Despite the potential synergies between integrating literacy and science instruction in service of students' knowledge building and engaging in scientific practices, there are a number of challenges to this integration in elementary classrooms. One challenge is the limited time that is allocated to science instruction in the United States. Teacher survey data from the 2015 National Assessment of Educational Progress (NAEP) science assessment indicate that over 50% of fourth-grade teachers reported dedicating fewer than three hours a week to science instruction (NCES, 2016). Thus, the majority of fourth-grade students in the United States have limited opportunities for science learning in a typical school week – an average of only thirty-minutes per day.

A second challenge is the poor quality of many of the texts available for science instruction. For example, Pearson et al. (2010) noted that the density of typical science textbooks is disengaging, and that science teachers' access to well-designed texts that are accessible to young readers is limited. Of course, simply making high-quality texts available in print or digital forms is not sufficient to ensure that students have opportunities to productively engage with those texts; rather, students need explicit instruction to develop and refine the literacy tools necessary for reading and writing in science.

Indeed, although science texts may provide opportunities for students to use reading, writing, and oral language to build and communicate knowledge about the world, they also pose challenges for young readers. While science texts contain rich content, they are often abstract and conceptually dense (NRC, 2014). For instance, science texts often use language in discipline-specific ways (e.g., explanations, arguments) that are unfamiliar to students, and differ greatly from the language used in narrative text (Palincsar, 2013). Fang (2006), for example, identified language demands specific to science texts, which become particularly salient as students move into the upper-elementary and middle grades. Some of these demands include the use of: (a) science vocabulary; (b) "everyday" words that have technical scientific meanings; (c) abstract and lengthy nouns; and (d) passive voice. Because of the challenges posed by scientific language, Snow (2010) called for collaboration between literacy and science curriculum designers and researchers to develop curricula and methods for supporting students to learn and use scientific language. The present dissertation study is responsive to this call, as the iteratively designed curriculum is the result of a collaboration among literacy and science education researchers and teachers.

In addition to scientific language demands, science texts frequently incorporate multiple forms of representation to communicate information about phenomena, such as print text, graphs, and diagrams. The demands of reading and interpreting multiple modes of information may pose comprehension challenges for young readers and instructional challenges for K-12 teachers. For instance, in a study of teachers' and students' use of multiple forms of representation in elementary science, Prain and Waldrip (2006) found that while teachers used various modes (e.g., verbal, visual, written, numerical, embodied), they did not systematically support students to make rich connections across modes. However, and pointing to usefulness of this practice for young students, study findings indicated that those students who *did* recognize relationships between multiple modes demonstrated better conceptual understanding than those who did not. Consistent with this finding, Siegel (2006) explained that when learners move across multiple modes or sign systems, they have opportunities to identify relationships between them, which in turn, may lead to more complex or deeper conceptual understandings.

Despite the potential benefits of supporting young students to synthesize information from multiple representational forms, Jian (2016) provided additional evidence that interpreting and integrating multimodal information in service of knowledge building, poses challenges for young readers. Jian (2016) conducted an eye-tracking study to investigate high-achieving fourth-graders' reading and learning from illustrated science text and found that the fourth-grade students made few references to both the illustration and the text within the reading task and struggled to integrate science information across modes. These findings suggest that elementary-grade students need support in order to closely analyze images in science texts and to identify relationships between information within prose and illustrations to support strategic integration of multi-modal information in service of knowledge building.

In conclusion, the expectations outlined in standards-based reforms, such as the CCSS and NGSS, place considerable demands on K-12 educators. Furthermore, these calls for standards-based reforms in both literacy and science instruction come at a time when our school-age population is increasing in its diversity as measured by primary-language, socioeconomic status, race, and ethnicity. Given these demands, instructional research has a unique role to play in supporting teachers. Using design-based research (DBR) and case study methods, in the context of elementary science instruction, this study seeks to understand how texts and tasks can be brought together in ways that create opportunities for and support students' knowledge building, and their development of foundational and scientific literacies as they engage in project-based learning.

In the next section, I review programs of research that have demonstrated promise for leveraging the synergies between literacy and science through integrating text and first-hand experience in the context of disciplinary inquiry. These lines of research have enhanced our understanding of the types of texts and experiences that are responsive to contemporary reform efforts in science and literacy.

Research on Literacy and Science Integration

The parallel calls for reform in literacy and science education have inspired programs of research that investigate the potential of integrated science and literacy instruction in the elementary and intermediate grades. These programs of research have explored what is possible when investigation-based science instruction integrates meaningful opportunities for students to use and develop the literacy tools of reading, writing, and speaking in service of knowledge building and engaging in scientific inquiry. For instance, we know from the studies of Cervetti et al. (2012), Fang and Wei (2010), Guthrie and colleagues (2004, 2009), Palincsar and Magnusson (2001), Romance and Vitale (1992, 2001), and Varelas and Pappas (2006) that science texts can be used in the elementary and intermediate grades to promote the development of vocabulary, fluency, and comprehension; foster student engagement and positive attitudes towards reading; identify intertextual connections among science texts and first-hand experiences; build science knowledge; and provide a context for and support students' engagement in scientific practices. In the following sections, I summarize the design and contributions of these lines of research, which lend support to the thoughtful integration of science and literacy instruction.

Concept-Oriented Reading Instruction (CORI). In a longstanding program of research, Guthrie and colleagues (e.g., 1999, 2004, 2009) incorporated opportunities for elementary-aged students to participate in meaningful literacy activities in the context of science learning. In CORI instruction, which is designed around conceptual themes (e.g., adaptations in life science), students participate in hands-on exploration of science phenomena, opportunities to select and read books of their choice, collaboration with peers, and reading strategy instruction. Focal reading strategies in CORI include using prior knowledge, self-monitoring, searching for information, and interpreting literary and informational text. CORI teachers support students to make connections across instructional activities by linking activities, contexts, materials. Finally, CORI instruction provides opportunities and support for students to communicate their conceptual understandings with personally and culturally relevant audiences (e.g., classmates or other student-chosen audiences) through creating posters, stories, poems, performances, videos, and written reports. Multiple studies of CORI instruction have identified positive relationships with science learning, reading comprehension, use of reading strategies, and reading engagement in elementary and middle grades classrooms (Guthrie et al., 1999; Guthrie et al., 2004; Guthrie et al., 2009). This program of research lends support to the claim that providing meaningful purposes for reading and writing, in the context of learning science, can provide engaging and supportive contexts for the science and literacy learning of diversely achieving students.

In-depth Expanded Applications of Science (Science IDEAS). Romance and Vitale (1992, 2001) designed and investigated one model of integrated science and literacy instruction in elementary classrooms, *In-Depth Expanded Applications of Science* (IDEAS). In treatment classrooms, the IDEAS approach replaced English language arts instruction with a two-hour block of time dedicated solely to the integrated literacy and science intervention. Students who participated in IDEAS received instruction in comprehension processes and read science informational texts. Instruction focused on teaching science concepts, engaging students in hands-on science activities using science practices, reading informational texts, developing concept maps, and journal writing. Multi-year findings indicated that Science IDEAS was effective for improving elementary students' understanding of core science concepts and reading achievement. In addition to achievement impacts, Romance and Vitale (2001) also found that treatment students had more self-confidence and positive attitudes toward reading in science.

In a more recent study of the Science IDEAS intervention, Vitale and Romance (2012) investigated the effectiveness of the curriculum adapted for grades one and two, which focused on supporting students' development of science knowledge in service of enhancing reading comprehension. The adapted intervention included 45-minutes of daily instruction for a full school year, in which reading, writing, and science were integrated. All aspects of instruction were guided by a thematic focus, which supported teachers to sequence science core ideas in ways that provided opportunities for students to build knowledge across lessons. During daily instruction, students engaged in active explorations of the natural world and developed skills related to components of scientific practice, such as conducting observations and measuring. Finally, reading and writing were integrated with science explorations and practices, focused on enhancing students' knowledge building around science ideas. Findings of the quasi-experimental study indicated that treatment students significantly outperformed students in control classes on assessments of both science and reading.

Guided Inquiry supporting Multiple Literacies (GIsML). In the Guided Inquiry supporting Multiple Literacies (GIsML) program of research, Palincsar and colleagues investigated the ways in which different text features influenced how teachers and students used text in the elementary grades in the context of inquiry-based science instruction. Palincsar and Magnusson (2001) explored the use of a particular genre of text to support elementary students' firsthand science investigations. This genre was modeled from a scientist's notebook and was designed to demonstrate scientific reasoning and to engage students in "second-hand investigations." Whereas first-hand investigations engage students in directly investigating phenomena by manipulating variables and recording observations and measurements, in second-hand investigations, children are supported to ask questions about others' investigations of phenomena by consulting text-based information. Thus, the scientist's notebook texts were designed to serve as a "catalyst for engaging in scientific practices," in contrast to traditional informational texts whose primary purpose is to provide information. Because of these differences, Palincsar and Magnusson (2001) hypothesized that the format of the notebook text would support young students to more critically read informational text. To understand differences between student learning and experiences using traditional versus notebook texts, the researchers compared the use of both text types in elementary classrooms. Based on pre- and post-assessments of student content knowledge, Palincsar and Magnusson found significantly higher knowledge gains for students who read the notebook text. Findings also indicated that students who read the notebook text assumed a more critical stance to the text, as hypothesized.

The GIsML program of research also identified a number of ways in which students' text-based and firsthand experiences worked synergistically to support knowledge building and scientific reasoning. For instance, Hapgood, Magnusson, and Palincsar (2004) found that the design of the notebook texts supported students' firsthand investigations and also provided a shared context in which elementary-grade students could (a) discuss how observations of real-world phenomena can lead to the development of testable questions, (b) analyze and interpret multiple forms of representation, (c) examine and use data as evidence to make claims, and (d) discuss others' reasoning as they engage in scientific inquiry. In other words, the researchers identified ways in which the design and enactment of the notebook texts provided and supported opportunities for elementary-grade students to engage in scientific practices. While these findings are promising, GIsML research also indicated that the teacher's role in mediating and leveraging the opportunities afforded by the notebook text was critical for facilitating student learning (Palincsar & Duke, 2004; Hapgood et al., 2004).

Palincsar and colleagues' research illustrates one way in which science text might be designed and used instructionally to engage young students in scientific inquiry and investigation. The GIsML work, as well as other elementary-grades interventions integrating science and literacy, in hand with the secondary examples identified previously, are aligned with the aims of the NGSS (2013), as well as the CCSS (2010) emphasis on reading and interpreting disciplinary texts for disciplinary purposes.

Seeds of Science – Roots of Reading. In a more recent study, Cervetti et al. (2012) investigated the effectiveness of an approach that integrated literacy with science in the upper-elementary grades. In this intervention, students read and wrote texts for the purposes of building and communicating knowledge about science. This approach, called *Seeds of Science, Roots of Reading*, was designed to engage students in first-hand experience, write notes and reports, read texts, and discuss core ideas and inquiry processes to support knowledge building in science. *Seeds and Roots* designers also embedded explicit instruction focused on cognitive strategies that are shared across the domains of reading and science (Cervetti et al., 2012). Thus, strategies such as summarizing, making predictions, evaluating evidence-based claims, and developing explanations, were the focus of instruction in the context of both scientific inquiry and reading. In the study of 94 fourth-grade classrooms, half of the teachers taught the integrated unit focused on science ideas related to light and energy, while the other teachers continued their regular literacy instruction and taught a science-only unit that covered the same science content. Cervetti et al. (2012) found that students who participated in the integrated science-literacy unit made significantly greater gains than their peers in a variety of areas, including science writing, vocabulary, and conceptual understanding.

Reading Infusion. Fang and Wei (2010) investigated the impact of inquiry-based science instruction infused with reading strategy instruction and high-quality science trade books, on sixth-graders' science learning and literacy development. The inquiry-based curriculum, which was used in control classrooms, focused on fostering students' interest in science, supporting students to build science knowledge and thinking skills, and engaging in scientific practices. The experimental group also used the inquiry-based science curriculum, with the addition of 15-20 minutes of explicit reading strategy instruction per week, and a home reading program that engaged students in reading and responding to science trade books on a weekly basis. The home reading program consisted of a set of 196 books that addressed a range of topics related to the inquiry-based science curriculum. Students in the experimental group were required to select one book per week and respond to a short set of questions about the book, such as time spent reading, a big idea that they learned, one thing they wondered about after reading, and how much they enjoyed the book. Findings indicated that students who participated in the reading infusion curriculum significantly outperformed students in the inquiry-only curriculum on measures of reading comprehension and vocabulary.

Read-alouds and intertextual connections. In a series of studies, Pappas, Varelas, and colleagues (Pappas, Varelas, Barry, & Rife, 2003; Varelas & Pappas, 2006; Varelas, Pappas, Kane, & Arsenault, 2007; Varelas, Pappas, & Rife, 2006) investigated the ways in which young students made connections across texts, and among texts and first-hand experiences, during interactive read-alouds in service of science knowledge building. In one study, Varelas and Pappas (2006) explored the intertextual connections made by first- and second-grade students and their teachers during information book read-alouds in the context of integrated science-literacy units focused on states of matter and phase changes. The units featured first-hand investigations, whole-class discussion, interactive read-alouds of children's information books, and writing and drawing activities. Analyses of intertextual connections that students made during interactive read-alouds revealed that intertextuality allowed children to leverage their ideas and everyday language as they moved toward conceptual understanding and use of scientific language. Throughout the course of instruction, the researchers also documented an increase in intertextual connections made to hands-on investigations of phenomena central to the units of study. Based on these findings, Varelas and Pappas (2006) argued that intertextuality provided critical intellectual scaffolds that supported students' learning of science concepts and use of scientific language. In another study focused on the same unit of instruction, Varelas, et al. (2006) found that intertextuality: (a) fostered students' engagement in sense making and grappling with complex science ideas; (b) facilitated students' articulation of ideas; and (c) created opportunities for students to introduce and build upon others' connections to texts.

While the findings of Varelas and Pappas are promising, we need to know more about the ways in which elementary-grades teachers and students might be supported to read and identify intertextual connections across multiple texts and experiences to build disciplinary knowledge. This dissertation study provides such opportunities, because the project-based science curriculum that serves as the context for the present study was designed to support teachers and students to both make connections across conceptually related texts, and to make connections among texts, students' prior knowledge, and classroom-based activities, such as first-hand investigations.

Across all of the programs of research reviewed above, findings suggest that conceptually-rich curricula have the potential to serve as a powerful instructional context for elementary students to learn and use the literacy tools of reading, writing, and speaking in order to build disciplinary knowledge and engage in disciplinary inquiry. However, we need to know more about the optimal design of texts and tasks in particular contexts and the ways in which this kind of instruction unfolds in the classroom over a sustained period of time. This need is consistent with Valencia, Wixson, and Pearson's (2014) call for increased attention to the pairing and scaffolding of texts and tasks, and associated learning goals. The present study is responsive to this call. The texts and task investigated in the present study were designed and selected to engage students in reading and interpreting multiple, multi-modal informational texts in service of building knowledge and engaging in scientific thinking and practices.

Furthermore, while previous research on the use of text in elementary-grades science instruction provides examples of the types of texts and instructional activities that support knowledge building and literacy development, we need to better understand how teachers and students respond to particular opportunities to use text in service of scientific inquiry. Additionally, we need to know more about the design of texts and tasks in reform-oriented science instruction, how these texts and tasks might be used to support the development of foundational and scientific literacies, and how to support teachers to use text effectively with their students in these instructional contexts. Thus, the design-based nature of this work is important because it allows for researchers to modify interventions as they are enacted in the classroom and across cycles of design and enactment to support student learning in particular contexts.

Along these lines, Greenleaf and colleagues (Greenleaf, C., Brown, W., Goldman, S. R., & Ko, M., 2013; Greenleaf et al., 2011) have argued that using texts as resources for engaging in the practices of science and scientific inquiry require major shifts in science instruction across grade levels. Thus, we need to know more about what texts and tasks might look like across grade levels, particularly in the elementary grades, when little guidance is provided in current standards-based reforms. While an emphasis on reading and interpreting text for disciplinary purposes is clearly outlined in the CCSS beginning in grade six, there are no explicit goals or guidance for addressing ELA standards in science at the K-5 level. This means that supports for teachers must be addressed in curriculum materials and professional development at this level. The present study's focus on investigating the design and enactment of texts and tasks, in the context of project-based science instruction, has the potential to inform this work.

Finally, we also need to know more about the challenges that teachers face in the classroom as they engage in this type of instruction. For instance, we know that elementary-grades teachers typically dedicate only limited time to science instruction (NAEP, 2015). Another challenge, noted by Pearson et al. (2010) includes the poor quality of science texts available to K-12 teachers. Findings from the present study have the potential to speak to ways in which curriculum designers and researchers might productively design and select high-quality texts and tasks. Further, elementary teachers, in particular, may experience challenges teaching science due to limited disciplinary knowledge. Findings from the present study may speak to the productive design of educative curriculum materials to support elementary-grade teachers to engage in this complex work with their students.

In conclusion, none of the integrated science and literacy programs of research reviewed were design-based, allowing researchers to design, evaluate and improve an intervention as it interacts with the contextual variables integral to enactment (Fishman et al., 2004). None of these studies engaged in the close study of the unfolding of the curriculum as it occurred over the course of an entire academic year, allowing researchers to investigate the ways in which the design of texts and tasks provided opportunities for and supported students' disciplinary knowledge building and literacy development across several units of instruction. These features are important contributions of the present study.

Investigating Texts and Tasks in Project-based Science Instruction

The present study is conducted in the context of project-based learning (PBL) in science (Blumenfeld et al., 1991). PBL is gaining momentum in K-12 classrooms as an approach to enhancing the relevance and rigor of students' learning experiences as they engage in the study of real-world problems and disciplinary content (Condliffe et al., 2017). Additionally, PBL hypothetically provides opportunities for students to read, interpret, and produce a wide range of text types as they explore real-world problems, including both published and student-created written texts, as well as multimodal texts in print and digital forms (Wade & Moje, 2001). Because of these features, PBL may offer a rich instructional context for supporting young readers to use text for knowledge building, acquire requisite thinking tools, read and write multimodal texts for disciplinary purposes.

Although interest in PBL as an instructional context has increased in recent years, there is a dearth of research focused on the design and enactment of PBL curricula, and the ways in which PBL instructional contexts might support students' literacy development, knowledge building, and disciplinary inquiry. This is particularly true for the elementary grades. While the research based is limited, some research suggests that PBL may serve as a powerful instructional context for supporting elementary-grade students' disciplinary knowledge building and literacy development (Halvorsen et al., 2012). Additionally, classroom research conducted at the secondary level, has begun to identify language- and literacy-learning opportunities and demands of project-based science instruction (Moje, Collazo, Carrillo, & Marx, 2001; Moje, Chiechanoski, Kramer, Ellis, & Carrillo, 2004). Despite emerging research, we know very little about how PBL contexts might be designed to provide opportunities for students to use – and to support young students' development of – foundational and disciplinary literacies. The present study has the potential to build upon this emerging body of research.

In conclusion, while students may experience multiple opportunities to read and produce multiple text types in the context of PBL, questions remain about whether and how the design and enactment of PBL curricula might recruit and support young students' development of foundational and scientific literacies, as they build science knowledge and engage in disciplinary inquiry. This is the focus of the present study. In particular, design-based studies are needed in order to understand whether and how texts and tasks designed for project-based science instruction may create opportunities for and support students' knowledge building and literacy development. In addition, the field needs research that explores systematic modifications that enhance the classroom use of text in service of knowledge building and engaging in scientific practices. The current study is designed to address these very questions.

Theoretical Perspectives

This study, which focuses on the design and enactment of texts and literacy tasks within a PBL intervention in elementary-grades science, calls for the use of multiple theoretical lenses, which are represented and have been advanced by the literature reviewed in this chapter. For instance, the RAND model of reading comprehension (RAND Reading Study Group 2002) illustrates the ways in which reading comprehension is a product of the interplay between a reader, text, and activity within a sociocultural context. Further, theories of multimodality (Kress & van Leeuwen, 2001) highlight the affordances and constraints of different representational forms, or texts, for building and communicating knowledge and have been brought to bear in literacy research specific to multimodal and digital literacies. Sociocultural perspectives (e.g., Wertsch, 1991) explain how learning and development are related to social, cultural, institutional, and historical contexts. Finally, tenets of constructivism (e.g., Brown, Collins, & Duguid, 1989; Dewey, 1916; Palincsar, 1998) illustrate learners' active construction of knowledge by working together to solve problems and by manipulating and using ideas, a variety of information sources, and cognitive tools. Each of these theories is important for understanding the ways in which the design and enactment of texts and tasks in elementary-grades project-based instruction might support students' foundational and disciplinary literacy development and knowledge building. Additionally, I used these theories in interplay as I informed the design of the instructional context and analyzed and interpreted my data. Below, I describe each of these theories and the ways in which they inform the present study.

RAND Model of Reading Comprehension

One theory guiding this research is drawn from the RAND Reading Study Group (2002), which proposed that reading comprehension can be explained and supported by considering the reader, the text, and the activity in which the reader and text are involved, as well as the larger sociocultural context in which the activity takes place. For instance, the reader brings prior word and world knowledge to the text and activity; the text may be characterized in terms such as genre, organization, and graphic features; attention to the activity indicates that reading is done for a particular purpose; and finally, attention to the sociocultural context recognizes that students are members of a classroom community as well as members of many communities beyond the classroom. Membership in these communities influences the resources students bring to reading and the ways in which students experience reading. I attended to each of these elements (reader, text, activity, and sociocultural context) in the present study as I investigated how texts and literacy tasks, designed for project-based science instruction, supported or constrained the knowledge building and literacy development of students in one third-grade class, who were diverse with respect to literacy achievement.

Drawing on the RAND model, Valencia, Wixson, and Pearson (2014) recommended increased attention to the pairing, scaffolding, and learning goals associated with the interplay of text and task components of the RAND model. Valencia et al. (2014) explained that closely examining the interactions among the reader, text, and tasks in particular contexts is necessary for understanding how reading comprehension varies across situations. A focus on the interplay between readers, texts, and tasks/activity, within a PBL instructional context, is one contribution of the present study.

Theories of Multimodality

Multimodal perspectives on literacy assume that people use many representational resources or modes, such as images, audio, and video modes, to make meaning (Kress & van Leeuwen, 2001). *Modes* are semiotic resources that have affordances and constraints for representing and communicating ideas, which influence sense making; language is but one of these modes (Jewitt, 2008). While theories of multimodality were not prominent in the reviewed research, multimodal perspectives were important to the research of Prain and Waldrip (2006). Prain and Waldrip (2006) highlighted the necessity of integrating multiple modes of representation to develop and communicate scientific knowledge, citing the affordances and constraints of different modes of representation for interpreting and communicating science ideas.

Lemke (2004) explained that scientific literacy and communication are inherently multimodal, and that scientific disciplines are "leading the way" in the use of video, animations, graphical displays, audio, and simulations to pursue research questions. This integration of print text and multimedia in scientific disciplines illustrates the ways in which scientific and multimodal literacy are fundamentally intertwined. Thus, in order to read, interpret, and produce science text in service of knowledge building and engaging in scientific practices, students must develop skills for interpreting and translating across multiple modes of representation. Multimodal perspectives on literacy are integral to this dissertation study because the texts, broadly defined, that students read, viewed, and interpreted assumed a variety of representations in both print and digital forms, including data tables, videos, written texts, images, and various combinations of these modes. Thus, theories of multimodality guided the design of texts and tasks within the focal intervention.

Sociocultural Perspectives on Learning and Development

I also approach this work with a sociocultural perspective, which is well-aligned with the tenets of project-based learning. Indeed, sociocultural theories of literacy have a tradition in this area of inquiry (e.g., Moje et al., 2001, 2004). For instance, the design of instructional interventions and analysis of data in the research of Hapgood et al. (2004), Moje et al. (2001), and Pappas et al. (2003) were informed by sociocultural theories of learning. A sociocultural perspective rejects the view that knowledge is located solely within the individual and, instead embraces the view that learning and understanding are inherently social, occurring through interaction, negotiation, and collaboration (e.g., Wertsch, 1991). In the present study, I focused on the classroom community, in which there were many opportunities for interaction and collaboration around reading and interpreting text, with particular attention to how these opportunities are taken up by students. Furthermore, from sociocultural perspectives, cultural activities (such as scientific modeling or explaining phenomena) and tools (such as computers and language) are integral to knowledge building. Investigating how students participated in cultural activities and used literacy tools in project-based science instruction called for the close study of the classroom community over sustained periods of time.

Further, the work of sociocultural theory is to explain how individual mental functioning is related to cultural, institutional, and historical context; hence, the focus of the sociocultural perspective is on the roles that participation in social interactions and culturally organized activities play in influencing psychological development. Wertsch (1991) proposed three major themes in Vygotsky's writing that illustrate the nature of the interdependence between individual and social processes in learning and development. First, individual development, including higher mental functioning, originates in social interaction. As learners participate in a broad range of joint activities and internalize the effects of working with others, they acquire new strategies and knowledge of the world. The close study of the classroom community enabled my analysis of joint activity and learning.

The second Vygotskian theme that Wertsch (1991) identified is that tools and signs, or semiotics, mediate human action. Semiotic means are the tools that facilitate the co-construction of knowledge and are internalized to support future independent problem solving. Part of the work of the present study was to understand the ways in which third-grade students' learning was mediated by semiotic means in the PBL curriculum and instructional context.

The third theme that Wertsch (1991) proposed from Vygotsky's writing is that the first two themes are best examined through genetic, or developmental, analysis. The data I collected and analyzed for this study include those that documented the interactions between learners and their teacher, and the contexts in which they participated as they read and interpret a variety of texts and engaged in related literacy tasks in project-based science instruction across the span of a school year.

Constructivism

Finally, the present study is informed by constructivist theories of learning. Similar to sociocultural theory, constructivism has a tradition in this area of inquiry. For example, constructivist theories of learning informed the design of instructional interventions featured in the studies conducted by Guthrie et al. (1999), Moje et al. (2001), and Romance and Vitale (1991). Indeed, Blumenfeld, Krajcik, Marx, and Soloway (1994) described project-based instruction as "one attempt to embody constructivist theory" (p. 540). Based on constructivist ideas of learning, students actively construct knowledge by working together to solve problems and by manipulating and using prior knowledge, ideas, a variety of information sources, and cognitive tools (Brown et al., 1989; Dewey, 1916; Palincsar, 1998). Marx et al. (1994) explained that constructivist theory underlies project-based instruction in at least four ways. In PBL, students (a) pursue meaningful problems; (b) develop multiple representations of understanding;

(c) engage in collaborative activity within a community of learners; and (d) use cognitive tools, such as computers, language, and texts to build and represent knowledge. Constructivist and social constructivist approaches to instruction, particularly science instruction, emphasize the importance of students being afforded opportunities to identify solutions to meaningful, real-world problems through engaging in scientific practices similar to those of practicing scientists: asking questions; designing and carrying out investigations; collecting, analyzing, and interpreting data; identifying and evaluating information from a variety of sources and multiple modes of representation; making claims based on evidence; and communicating investigation findings.

Theoretical Perspectives in Interplay

In conclusion, one contribution of the present study is working at the intersection of the theoretical perspectives described to inform the design of the PBL instructional intervention, as well as to guide data collection and analysis in the present dissertation study. Sandoval (2014) described the design of instructional interventions as a theoretical activity (see also Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003). In other words, instructional interventions embody researchers' hypotheses about the ways in which learning occurs in particular contexts, as well as how to support learning in those contexts. Recall that Blumenfeld et al. (1994) described the ways in which the design of project-based learning interventions was guided by constructivist theory. I also adopt this view, as the PBL instructional intervention featured in the present study was designed to support student learning by engaging elementary-grade students in (a) pursuing meaningful problems; (b) developing multiple representations of understanding; (c) engaging in collaborative activity within a community of learners; and (d) using cognitive tools, such as computers, language, and texts to build and represent knowledge.

In interplay with constructivist theory, sociocultural theories of learning and development guided the design of the instructional intervention and analysis in the present study. Recall that, from sociocultural perspectives, cultural activities (such as scientific modeling or explaining phenomena) and tools (such as computers, language, and texts) are integral to knowledge building. The NGSS calls for students to engage in disciplinary practices, which can be thought of cultural activities. Students' engagement in the practices of science is an important element of the design of the instructional environment. Further, the design of tools in the PBL learning environment included the design of texts, software, and other resources to support student learning. Investigating how students participated in cultural activities and used literacy tools in project-based science instruction called for the close study of the classroom community over sustained periods of time.

Further, the RAND Reading Study Group (2002), heavily guided the data collection and analysis in the present study. In this study, I looked closely at the interplay between readers, designed or selected texts, and the designed activity or tasks in which the readers were involved. Further, the instructional intervention – elementary-grades project-based science instruction – was an important part of the sociocultural context in which the activity takes place, as the design commitments of project-based instruction guided the design of texts and tasks featured in the present study. Theories of multimodality informed, specifically, the design and selection of texts in multiple representational forms. This is called for in the CCSS for ELA. In addition, as described previously, multiple representational forms are particularly important for the building and communicating knowledge in science, as scientists must interpret multimodal texts such as print text, images, simulations, graphical representations, and video to interpret and communicate about science phenomena. Therefore, theories of multimodality guided the design of texts and tasks within the project-based instructional intervention.

In this section, I described the ways in which the design of the project-based learning intervention, and the texts and tasks within it, were informed by multiple theoretical perspectives on how learning might occur or be supported. In the next chapter, I describe the design of my study and my methods of analysis. In this context, I introduce and describe my development and use of *conjecture mapping*, which Sandoval (2014) defined as "a means of specifying theoretically salient features of a learning environment design and mapping out how they are predicted to work together to produce desired outcomes." (p. 19). In other words, conjecture mapping is a systematic approach to design-based research, which allows the researcher to articulate both design and theoretical conjectures, which are embodied in a particular learning environment. In this way, I use conjecture mapping to identify theoretically salient features of the design of the MLs intervention specific to literacy integration, the ways in which the theoretically salient features work together to support student learning, and the intervention's theoretical commitments as embodied in the design. Finally, I use conjecture mapping as a tool for guiding data collection and analysis, in order to examine the ways in which design and theoretical conjectures played out in the project-based learning intervention, as it was enacted in a particular context.

CHAPTER III: RESEARCH METHODS AND DESIGN

While project-based learning approaches hypothetically provide opportunities for students to read, interpret, and produce a range of texts as they explore real-world problems, we know very little about how young children and their teachers respond to such literacy learning opportunities. I designed and conducted this dissertation study within a larger design-based research (DBR) project (Brown, 1992; Collins, 1992) focused on the design, evaluation, and improvement of an intervention as it interacts with the contextual variables integral to enactment (Fishman et al., 2004). In this dissertation study, I used DBR and case study methods (Stake, 1995) to examine the design, enactment, and improvement of texts and tasks designed for use in an elementary project-based learning intervention, which integrates science, English language arts, and mathematics. Specifically, I investigated how texts and literacy tasks designed for elementary project-based science instruction supported, or constrained, the knowledge building and literacy development of students, with diverse literacy achievement profiles, in one third-grade classroom.

First, I used conjecture mapping (Sandoval, 2014), a systematic approach to DBR, to identify theoretically salient features of the design of the instructional intervention, specific to literacy integration. I focus specifically on the design of texts and text-related tasks integrated in the PBL curriculum, and map how these features are predicted to work together to produce specific outcomes. Conjecture map development guided my data collection, analysis, and case study construction.

Case study research is a study of a bounded system (Barone, 2011). The bounded system under investigation in this study was one third-grade classroom, engaged in the enactment of Multiple Literacies project-based science instruction. This study is an *instrumental case study*, which Stake (1995) described as being motivated by “a research question, a puzzlement, a need for general understanding, a feel that we may get insight into the question by studying a particular case” (p. 3). Thus, I designed this study to investigate the issue of *the design and enactment of texts and related literacy tasks in the context of PBL*. To this end, I selected one bounded case – one class of third-graders and their teacher engaged in a PBL intervention – in order to use one example to explore and illustrate this issue. In order to respond to my research questions, I investigated, analyzed, and described the designed texts and tasks and their enactment within the focal third-grade classroom. Across findings chapters, I report assertions based on my analyses of multiple sources of data and strive to provide a thick description my findings (Merriam, 2009).

Instructional Context

Using Multiple Literacies in Project-based Learning

The instructional context in which I conducted this dissertation study is *Using Multiple Literacies in Project-based Learning* (MLs). The MLs project is a cross-institution collaboration with the aim of developing iteratively designed, integrated project-based science, literacy, and math curricula for the elementary grades. In grade three, students participate in four, six- to nine-week, units that address the three dimensions of the Next Generation Science Standards (NGSS, 2013) and select Common Core State Standards for English language arts and mathematics. Each unit is framed by a driving question: (1) *Why do we see so many squirrels but can’t find any stegosauruses?* (2) *How can we design fun moving toys that any kid can build?* (3) *How can we* *help the birds around here grow up and thrive?* (4) *How can we grow plants for food in our community?*

The MLs units are designed to draw on students' funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992) and to engage students in using a variety of text resources and multiple literacies (e.g., foundational, scientific, multimodal literacies) as they investigate and make sense of science phenomena. Additionally, the units are designed to include features consistent with characteristics of project-based science instruction (e.g., Blumenfeld et al., 1994). For example, in addition to framing each unit with a "driving question" that is both meaningful to students and anchored in real-world problems, students participate in hands-on investigations and other science and engineering practices; create artifacts in pursuit of the driving question; collaborate with peers, teachers, and others in the community; and use cognitive tools, such as digital technologies, to scaffold their collaboration, inquiry, and learning. In the following findings chapters (IV-VII), I focus on each of the four third grade units of instruction, which I describe further in these contexts.

Research Context

School Context and Participants

I conducted this study during the 2016-2017 school year in one third-grade classroom in Slate Elementary School, a K-5 elementary school located in a rural district in the Midwestern United States (all names of places and people are pseudonyms). According to census data, 20% of children in the district live below the poverty line; further, district profiles identified 45-50% of students as economically disadvantaged, based on eligibility for free or reduced-price meals, living in households receiving food or cash assistance, or due to being migrant, homeless, or in foster care. Slate Elementary School is a Title I school that serves 550 students; at the time of the study, 65% of the students qualified for free or reduced-price lunch, 20% received special education services, and 5% were English learners. Twenty-five percent were African American, 5% were Hispanic/Latino, 5% were two or more races, and 65% were white. Only 20% of students demonstrated proficiency in English language arts on the state's standardized measures of academic achievement.

The teacher, Ms. Lane, is an experienced elementary school teacher and was a second-year participant in the *Using Multiple Literacies in Project-based Learning* (MLs) project at the time the study was conducted. There were 31 students in her class (12 were female, 19 were male), with demographics reflective of those of the larger school population. At the beginning of the 2016-2017 school year, the reading levels of the students in Ms. Lane's class ranged from kindergarten through fifth grade.

I purposefully selected (Patton, 1990) Ms. Lane's class as the context for this dissertation study because of her history of participation the MLs curriculum project. I had observed and collected data in Ms. Lane's classroom as a part of the Multiple Literacies curriculum design and research team during the previous school year (2015-2016), during which time I was able to develop a relationship with her in this context. Thus, I knew that her classroom would serve as an "information rich case" (Patton, 1990, p. 169), in which I could collect data that would allow me to thoughtfully respond to my research questions specific to the design and enactment of texts and tasks in the context of elementary project-based science instruction.

The focal class participated in all four MLs project-based science units designed for grade three. Typically, the teacher taught science every day, for 30-75 minutes, depending on the day's schedule. Occasionally, science was cancelled due to field trips, assemblies, or other special events that were scheduled during the school day. If time was limited on a particular day, the teacher frequently “made up” this time on subsequent days in order to complete as much of the curriculum as possible. On average, daily MLs project-based science instruction lasted 45 minutes.

Focal participants. While I focused on the entire class during classroom observations, I also selected sixteen focal students (approximately half of the class) for participation in interviews and analysis of student-generated artifacts, using a purposive approach (Patton, 1990). I selected the sixteen focal students because they (a) were diverse with respect to reading achievement based on teacher ratings, reading group assignments (i.e., intervention [Title I or Resource Room], low, middle, and high performing), and scores on benchmark assessments (e.g., NWEA Measures of Academic Progress, 2003); and (b) reflected the diversity of the class with respect to their gender and race/ethnicity (see Table 3.1). Thus, I sought maximum variation in the sample, a strategy which enhances transferability in qualitative research by allowing for the possibility of a wider range of application by the audience (Merriam, 2009). Focal participant demographic data was drawn from student records provided by the classroom teacher.

The diverse literacy profiles of the focal students enabled me to investigate whether and how texts and literacy tasks designed for project-based science instruction might differentially support, or constrain, students’ knowledge building and development and use of foundational and scientific literacies in this context. Finally, and relevant to my second research question, it is possible that students who demonstrate different levels of literacy achievement require different types of modifications to texts and tasks in order to optimally support their learning from and use of text in this context.

Table 3.1

Focal Participant Demographics

Name	Gender	Race/Ethnicity Identification	Reading Group	Fall 2016 Reading MAP Percentile
Jenna	Female	White	Intervention	4th
Leon	Male	Black	Low	1st
Malik	Male	Black	Low	31st
Carter	Male	White	Middle	43rd
Ellie	Female	White	High	78th
Owen	Male	White	High	29th
Aiden	Male	Multi-Racial	High	90th
Raven	Female	Black	Middle	78th
Nick	Male	White	Low	8th
Makayla	Female	Multi-Racial	High	89th
Keyanta	Female	Multi-Racial	Intervention	21st
Lucas	Male	White	Middle	48th
Christian	Male	White	High	56th
Zayn	Male	White	Middle	53rd
Brandon	Male	White	Resource Room	9th
Julia	Female	White	Intervention	12th

Role and position of the researcher. Throughout the duration of the study, I acted both as a participant observer in Ms. Lane's third-grade classroom, and as a member of the MLs curriculum design team. Within the classroom, my primary goals were to conduct classroom observations during MLs project-based science instruction, interview the focal students and Ms. Lane about the curriculum texts and literacy tasks at the conclusion of each unit of instruction, and to collect class- and student-generated artifacts. As a member of the curriculum design team, I contributed to all aspects of MLs curriculum design (e.g., development of lesson plans and teacher and student resources) and analyzed and used the data collected in the classroom to inform revisions to the curriculum.

Early in the school year, Ms. Lane explained to her class that I was one of the designers of the MLs science curriculum resources and that I would come to the classroom to video- and audio-record science instruction. Further, I explained that I was very interested in learning about what the students did in science, how they used and learned with the MLs resources, and their opinions about the curriculum. I told the students that most of the time during science instruction, I would be very busy taking notes about what they were doing on my laptop. However, I became involved in classroom interactions in the following instances: (a) the teacher and or students invited me to be involved, or (b) the teacher requested clarification or advice regarding the design or intended use of curriculum materials or the digital devices that students used to access digital curriculum resources. While the teacher delivered all MLs instruction, I frequently helped troubleshoot technology issues, supported students to navigate the use of digital tools (e.g., Chromebooks), and answered students' questions about curriculum materials or their classwork.

The students regularly invited my involvement throughout the year-long study. For instance, prior to the beginning of science instruction in the afternoons, students often had stories from home or earlier in the school day that they hoped to share. Additionally, I tied shoes, retrieved tissues, loaned pencils, helped with coat zippers, and facilitated clean-up following science instruction. As the year progressed, I modified my schedule as possible so that I could both satisfy students' invitations of my involvement (outside of science instruction) while maintaining my focus on data collection during the enactment of the MLs curriculum units. For instance, in addition to video- and audio-recording, observing, and collecting field notes during MLs project-based science instruction, at the teacher's invitation, I arrived early to read with individual or small groups of students during independent reading time, frequently joined the class for recess immediately following science instruction, and attended special events during the school day, as possible (e.g., chorus concerts, field day, and last-day of school events). These additional interactions outside of data collection were beneficial to the extent that they allowed me to build rapport with the third-graders and their teacher.

At this point, it is important to explain my "position" as a researcher. Lincoln and Guba (2000, p. 183) refer to this as "the process of reflecting critically on the self as a researcher, the 'human as instrument.'" In the text that follows, I explain my experiences, assumptions, dispositions, and biases as they relate to the conceptualization and conduct of this dissertation study. I grew up in a small (predominantly white) town within a rural community in the southern United States. Many of the women in my family were primary- and elementary-grades teachers. My mother was a first-grade teacher for the majority of her teaching career. Our home was filled with books, which my family read frequently, in addition to regularly visiting the local library. I began kindergarten at age four and became a fluent reader at this time. I developed an early love of reading and literacy and a life-long passion for the processes involved in literacy teaching and learning.

During my teaching career, I worked with sixth-, seventh-, and eighth-grade students, identified with a variety of learning and behavior disorders, across content area courses and in reading intervention classes. Many of these students struggled to learn to read and write, and to use reading and writing as tools for building knowledge in their content area classes, such as science and social studies. During teaching, I became aware that the vast majority of my students were from low socioeconomic status backgrounds. Indeed, the demographics of the school and community in which I taught were, in many ways, similar to the demographics of the focal elementary school featured in this study. My teaching experiences fueled my interest in exploring literacy learning processes and outcomes for students with diverse learning profiles and needs, as well as the relationships between literacy learning and sociocultural factors that shape students' experiences in K-12 classrooms. I pursued these interests as I earned my doctorate and began to design and investigate instructional interventions aimed at supporting the literacy learning and disciplinary knowledge building of diverse young readers, engineering and researching instructional contexts that might “level the playing field” for traditionally marginalized groups of students. As discussed in my review of the literature, PBL is one such instructional approach that is hypothesized to ameliorate opportunity gaps for diverse learners.

In addition to my own experiences and dispositions, another of my biases is reflected in my high regard and deep respect for Ms. Lane’s teaching. My admiration of the thoughtfulness she brings to her teaching; the relationships she builds with her students and their parents; her openness to, interest in, and commitment to reflecting upon and improving her teaching practice; and the classroom community that she builds and fosters has only increased in the three years that I have worked with her in the context of the larger MLs research project. Indeed, this is part of the reason that I chose to collect and analyze data in her classroom.

My experiences as a former middle-school special education teacher and as a literacy researcher influenced the research questions I posed in this study, the theoretical perspectives and lenses that I brought to this research, and the interpretations I made as I conducted this qualitative study and reported my findings. In addition, I hold certain biases with respect to Ms. Lane’s teaching, which I have addressed by searching for data that might challenge or disconfirm expectations that I held related to the ways in which teaching and learning might unfold in Ms. Lane’s classroom. While I made every effort to reduce researcher bias and enhance internal validity (described further at the end of this chapter), my experiences and perspectives contributed particular lenses through which I viewed this research and informed my analysis and interpretation of the data I collected for this study.

Research Design

Overview of Design

I designed and conducted this dissertation study within a larger DBR project (Brown, 1992; Collins, 1992). One affordance of DBR is that it has the potential to address issues, such as the role of context in the enactment of curriculum and instruction that are especially relevant to practitioners (Bradley & Reinking, 2011). For this dissertation study, I focus specifically on the design, enactment, and iterative development of a set of texts and related tasks within the MLs project-based science curriculum across one year of enactment.

Sandoval (2014) proposed conjecture mapping as an approach to conducting systematic DBR that involves mapping design and theoretical conjectures through the design of a novel learning environment. Because the MLs curriculum is a comprehensive instructional intervention, with many features hypothesized to support knowledge building and literacy development, I used conjecture mapping to identify theoretically salient features of the intervention related to literacy integration and to map how these features are predicted to work together to produce specific outcomes (see Figure 3.1). For this dissertation, I analyze conjectures focused on the design and selection of MLs texts and related tasks.

To illustrate, my *high-level conjecture* is that – for students who demonstrate diverse levels of reading achievement – deep science and literacy learning with text require the use of literacy tools of reading, writing, viewing, and discussing for meaningful purposes in the context of PBL. One feature of the designed MLs curriculum included the *tools and materials* in the form of literacy resources (e.g., texts of multiple modes, media, and genres), digital tools, and teacher supports (e.g., lesson plans, interactive reading guides). For evidence of the *mediating processes* that enable the tools and materials to support desired outcomes, I observe specific interactions between the teacher and the students and among students and analyze class- and student-generated work around text reading and related literacy tasks. Examples of *desired outcomes* include students: (a) making sense of and synthesizing multiple multimodal science texts, (b) using science ideas and practices to make sense of and explain phenomena, and (c) developing increasingly sophisticated written and visual science texts. In my analyses and findings for this dissertation study, I foreground the literacy *tools and materials* in interaction with other features of the MLs *embodiment* (e.g., participant structures, tasks) and *mediating processes* to respond to my research questions.

I revisited my conjecture map as the curriculum unfolded in the classroom. For instance, I evaluated and refined original conjectures based on collected data and used my analyses to identify features of the literacy *tools and materials* and the teacher's enactment (e.g., *mediating processes*) that supported or constrained *desired outcomes* related to students' knowledge building and literacy development. These analyses supported me to identify modifications to the designed texts, tasks, and teacher resources that may enhance effectiveness or reduce identified constraints. Thus, mapping and analyzing conjectures concurrent with enactment allowed me to plan for modifications to designed or selected texts, tasks, and features of teacher and student resources to better approximate desired outcomes in future iterations of the curriculum.

Sandoval emphasized, "Testing a conjecture requires methods that can identify whether the expected mediating process does in fact emerge and that can provide evidence to trace that process back to designed elements" (2014, p. 24). As I describe in this chapter, to identify whether expected meditating processes emerged, I used qualitative and case study methods to analyze multiple data sources, such as qualitative field notes and videos of lesson enactment, interviews with focal students and the teacher, and student- and class-generated artifacts. For example, observable interactions were revealed through student and teacher activity and talk in the classroom, which were captured in field notes and video recordings. Teacher and student interviews produced additional data specific to both *mediating processes* and the *embodiment*. These multiple data sources allowed me to closely analyze observable classroom interactions as well as participant artifacts outlined in my conjecture map. Analyzing multiple data sources, in hand with the written curriculum, provided the evidence needed to trace observable interactions and participant artifacts back to designed elements of the curriculum. I illustrate this interplay through constructing and reporting a case.

While I was able to make some modifications to features of texts, tasks, and teacher resources within and across units of instruction, the full year of enactment (four units of instruction) is a single iteration of the MLs curriculum. Thus, while I highlight instances in my findings chapters in which I made design modifications within and across units, my findings primarily point to design modifications to be instantiated and further tested in the next iteration of the intervention, or year of enactment. In other words, while I made some modifications to features of the designed intervention within and across units in the focal classroom featured in this dissertation study the MLs team collaborates to make substantive iterative revisions during the summer between enactment cycles.

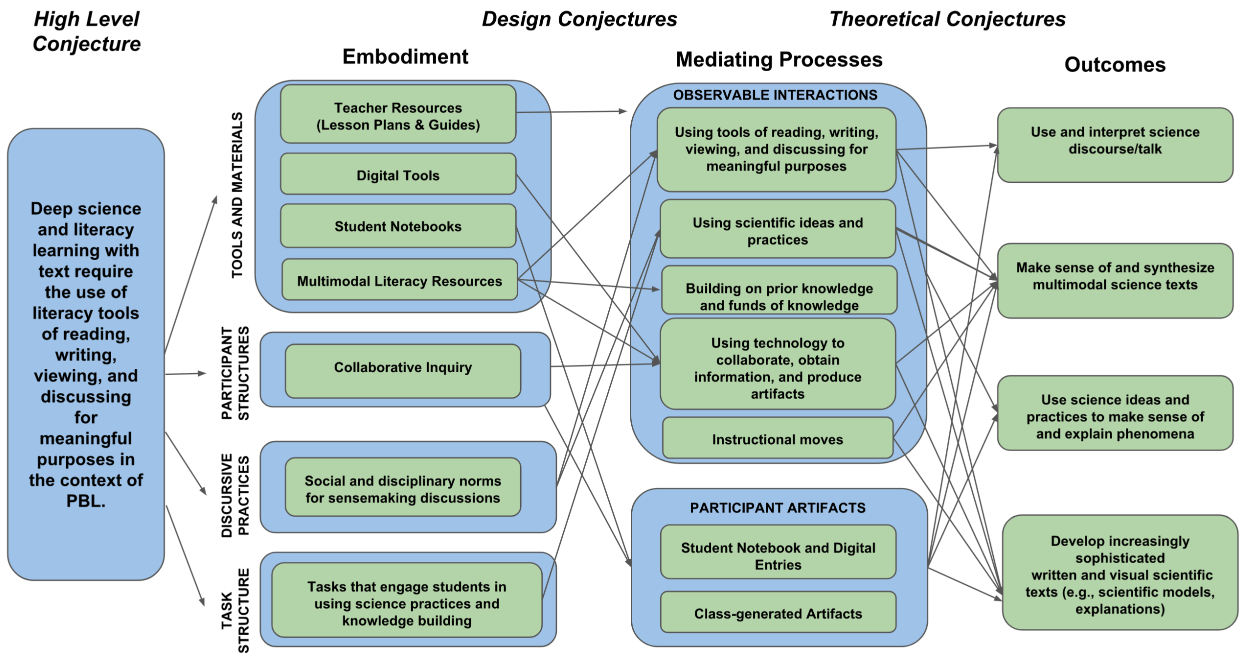

Figure 3.1. Conjecture map for supporting science and literacy learning with text in PBL.

Overview of Data Sources

Primary data sources for this study included (a) classroom observations, (b) semi-structured interviews with focal third-grade students and their teacher, (c) class- and student-generated artifacts, (d) the designed MLs curriculum, and (e) student records (Table 3.2). I analyzed data from each of these sources in order to discern the ways in which the texts and literacy tasks designed for – and enacted in – project-based science instruction supported, or failed to support, third-graders' knowledge building and development of foundational and scientific literacies. Analysis of the written curriculum, in concert with enactment data, enabled me to identify modifications to the written curriculum, specific to texts and literacy tasks, which might better support diverse students' knowledge building and literacy development, and the teacher's enactment of the written curriculum.

Collecting a variety of data sources allowed me to construct cases that painted a rich picture of life in the focal third-grade classroom, and to uncover "a converging line of inquiry"

(Yin, 1994, p. 92). In other words, drawing on multiple data sources allowed me to build a compelling case for my findings. To bolster the study's internal validity, I triangulated analyses by making comparisons across data sources, for example, by cross-checking the content of lesson enactment transcripts with semi-structured interviews and classroom artifacts (Merriam, 2009). In the sections that follow, I describe each of the data sources that I collected and analyzed for the study.

Table 3.2

Overview of Data Sources

<table>
<tr><th colspan="3">Data Source</th><th>Duration or number</th><th>Participants involved</th></tr>
<tr><td>1</td><td colspan="2">MLs written curriculum</td><td>Collected as enacted</td><td>n/a</td></tr>
<tr><td>2</td><td colspan="2">Classroom observations</td><td>Observed 130 hours</td><td>All students whose parents consented</td></tr>
<tr><td>3</td><td colspan="2">Semi-structured Interviews</td><td>Conducted 71
(4-5 interviews per focal student; 3 teacher interviews)</td><td>Focal Participants</td></tr>
<tr><td>4</td><td colspan="2">Class-generated artifacts</td><td>Collected as enacted</td><td>All</td></tr>
<tr><td>5</td><td colspan="2">Student-generated artifacts</td><td>Collected as enacted</td><td>Focal Students</td></tr>
<tr><td rowspan="2">6</td><td rowspan="2">Student records</td><td>Reading achievement data</td><td>Collected Fall 2016</td><td>All</td></tr>
<tr><td>Reading group assignments</td><td>Collected Fall 2016</td><td>All</td></tr>
</table>

Observations. My data collection for this study included qualitative observations of all MLs lessons enacted in the focal third-grade classroom during the 2016-2017 school year, which consisted of 130 days of project-based science instruction. I was present to conduct observations 120 of these days, beginning data collection shortly after the beginning of the school year in September 2016, and concluding data collection near the end of the school year in June 2017. On days that I was unable to observe, another member of the MLs research team did so. During observations, I recorded qualitative field notes using an open-ended observation template, in which I focused on the activity in which the students and their teacher were engaged, whole-class and small group discourse, and the ways in which curriculum resources were used during instruction. All observed lessons were also videotaped. Merriam (2009) explained that spending extended time collecting data in the field, establishes credibility for a case study, and enables the researcher to argue that what has been observed and reported represents patterns as opposed to irregularities.

Focal lessons for my study included those in which students were engaged in reading text (broadly defined) or related tasks. Thus, similar to Brenner et al.'s (2009) focus on "Eyes on Text Events," my focal observations and qualitative field notes focused on those instructional events in which students were engaged in reading text, but also included events during which students used information from text, such as writing or discussing in response to reading, synthesizing ideas from multiple texts orally or in writing, or using information from text to support engagement in scientific practices, such as scientific modeling, planning and conducting investigations, or developing scientific explanations. Because text reading and related tasks often spanned multiple days of instruction, and because the MLs lessons were designed to leverage students' prior knowledge and experiences, documenting and uncovering the ways in which the units unfolded in order to situate the enactment of texts and related tasks within the larger unit of instruction, required daily observation and data collection.

Interviews. I conducted semi-structured interviews with each of the sixteen focal students in my study. I audio recorded and transcribed all student interviews. Each focal student participated in four semi-structured interviews, one at the conclusion of each unit of instruction. The interviews focused on students' recall of, learning from, opinions about, and reflections on their experiences reading and using the texts designed or selected for use in the MLs third-grade units. All student interviews were, on average, 15 minutes in length, and ranged from approximately 10 to 20 minutes.

Student interviews for Units 1 and 4 followed a similar format and were designed to elicit focal students' responses to several texts from the units of instruction. In these interviews, I presented individual focal students with each of the texts from the unit, which were used as interactive read-alouds (six texts each for Units 1 and 4). After laying each of the six texts out on the table for the student to see, I asked the student to identify (a) which text they learned the most from, what they remembered about the text, why it was helpful to their learning, and whether we could make any changes to the text to help them learn more; (b) which text was the most interesting and what was interesting about it; and (c) which text their teacher should keep for next year if she could only choose one (or two) and why; and (d) whether there were any texts their teacher should skip with future classes and why. Finally, the semi-structured interviews for Units 1 and 4 concluded with questions focused on text sets that were designed for the units, from which students chose one or more texts to read (e.g., Do you remember which text(s) you read from this set? What do you remember about the text(s)?).

Unit 2 included only two whole-class interactive read-alouds and one text set from which students selected a text to read. Because fewer texts were included in this unit, I was able to design and ask focused questions about each of the texts. For instance, regarding the texts that were used for interactive read-alouds, I asked each focal student: (a) What do you remember about this text? (b) How was this text helpful to your learning? (c) Is there anything we could change to make this text more helpful to your learning? Unit 3 followed a similar format, eliciting students' responses to each of the texts they read during the unit of instruction, as well as how they navigated and use the information in particular texts. One unique question for the Unit 3 interview prompted students to identify which texts, from a set of supplemental texts, they independently sought out and read during the unit of instruction.

Data collected from semi-structured student interviews were important for eliciting students' reactions to and learning from texts designed and selected for the third-grade MLs curriculum units. Because all students did not always have the opportunity to share their ideas and reactions to texts during instruction (in the context of reading, viewing, and whole-class discussion), the text-focused interviews were important for uncovering what students recalled about and learned from unit texts. Additionally, in Units 1 and 4, I was able to uncover students' perceptions of unit texts by asking students which texts they learned the most from, which were the most interesting, and which were the most and least important for their teacher to use with future students. Across units, student interviews were helpful for eliciting students' thinking about design changes that should be made in order to help them learn more from particular texts. Finally, in the Unit 3 interview, I was able to uncover which students sought out supplemental texts that were topically related to the unit and the frequency with which they did so.

I also conducted semi-structured interviews with the teacher focused on the integration of literacy in each unit of instruction. I conducted the Unit 1 and 2 interviews at the conclusion of each unit of instruction and combined the Unit 3 and 4 interview protocols into a single interview conducted at the conclusion of Unit 4, due to the busy schedule near the end of the school year. In semi-structured interviews with the teacher, I asked about (a) her experiences engaging students in reading, writing, and oral language as they participated in project-based science instruction; (b) which of the texts she would choose to keep if she could only keep one to use with future students and why; (c) which of the texts she would choose to eliminate in the future and why; (d) her experiences using designed supports (e.g., lesson plans, interactive reading guides) for enacting the texts designed and selected for the MLs curriculum; (e) her reactions to and feedback on specific texts and tasks from the units of instruction; and (f) her reflections on students' engagement, interest, and learning with text during MLs instruction and the ways in which she supported students to read and learn from text in this context.

Class- and student-generated artifacts. In addition to conducting observations and interviews, I also collected class- and student-generated artifacts, such as student- and class-written explanations, student- and class-developed scientific models, and written responses to texts. These artifacts provided evidence of the ways in which students' incorporated ideas from text in student- and class-generated products, and insight into students' foundational and scientific literacy development.

Beyond collecting class- and student-generated artifacts created during project-based science instruction, I also collected student records, provided by the teacher. These records included demographic, school, and assessment data for all students in the class. Demographic and school data included students' guardian-reported race/ethnicity and gender data, as well as special education placement, reading group assignment (e.g., resource room, low, middle, high), and attendance information. Assessment information included students' scores on ELA benchmark assessments (e.g., NWEA Measures of Academic Progress, 2003) taken throughout the academic year. I used this information to select focal students who were representative of the class with respect to gender, race/ethnicity, and academic achievement.

Data Management, Preparation, and Methods of Analysis

In order to manage and analyze the large quantities of data I collected for this study, I first designed a data management system and analytic approach. Using the University of Michigan secure M+Box site, I organized and stored data by data source. For instance, I used this site to store and organize interview audio files and transcripts; qualitative field notes from classroom observations; student- and class-generated artifacts; and each of the unit texts, teaching guides, and lesson plans. In the sections that follow, I describe my approaches and processes for data preparation and analysis. In doing so, I create an "audit trail" in which I illustrate the ways in which I made decisions and arrived at my results throughout my inquiry (Lincoln & Guba, 1985).

Time-use analysis. To begin the process of data organization and analysis, I engaged in a time-use analysis, which resulted in the development of an "enactment timeline" of Multiple Literacies instruction in Ms. Lane's classroom for the 2016-2017 school year. Working from my qualitative field notes, I created an enactment timeline chart (see chart excerpt in Table 3.3) for each of the four units of instruction enacted in the focal classroom. The chart outlined the date on which each MLs lesson was enacted, each lesson activity enacted on this date, and the duration of instruction. Development of the enactment timeline through time-use analysis, allowed me to identify potential focal lessons (e.g., those in which students were engaged in reading text or in text-related tasks). Later in the analytic process, I engaged in a more detailed time-use analysis for individual lessons, as I analyzed focal instructional events to construct my case.

Table 3.3

Example Enactment Timeline

Date	Lesson and Activities	Time
5.31.17	**Lesson 2.6: How did the different conditions affect the traits of our plants?** • ***Activity 1:*** Students revisit observations. Teacher introduces lesson DQ and tells students they will analyze and interpret their class graphs to make a claim. • ***Activity 2:*** Students examine patterns within the data and make claim supported by the evidence. • ***Activity 4:*** Students begin interactive reading about plant growth. **Text:** Ms. Ollie's Plant Investigation	55 minutes
6.1.17	**Lesson 2.6: How did the different conditions affect the traits of our plants?** • ***Activity 4:*** Finished interactive reading about plant growth. • ***Activity 5:*** Previewed next lesson. **Text:** Ms. Ollie's Plant Investigation	60 minutes

Selection and analysis of observation data. My analyses of enactment data were the primary analyses for this dissertation study. In my selection of instructional events (the enactment of MLs texts and related tasks), I aimed to select texts and tasks that (a) were diverse in genre (e.g., biographical, hybrid narrative and informational, historical nonfiction, etc.), (b) featured multiple modes of representation (e.g., traditional print text, images, video, graphical, etc.), (c) featured diverse participation structures (e.g., whole class, small group/partner, individual), and (d) engaged students in a variety of tasks (e.g., creating scientific models, developing scientific explanations, planning and enacting first- or second-hand investigations, making sense of core science ideas or practices). Thus, sought diversity with respect to the types of texts and tasks analyzed and reported on in my findings chapters. My selection of texts for close analysis was also guided by students' interview responses, which I describe in the following section. For each unit, I selected two MLs texts and tasks, resulting in a total of eight text-task instructional events analyzed and presented in this dissertation study. See Table 3.4 for an overview of the texts featured in each findings chapter.

Table 3.4

Focal Texts and Tasks Selected for Analysis

Unit	Focal Texts	Focal Tasks
Unit 1: Why do we see so many squirrels but no stegosauruses?	For Squirrels, It's Headfirst and Down (researcher-designed text)	Developing scientific models
	Organism Structure-Function Texts (researcher-designed text set)	Developing scientific models
Unit 2: How can we design fun moving toys that other kids can build?	From Water Squirter to Super Soaker: How Lonnie Johnson Changed Water Games (researcher-designed text) PAIRED WITH Whoosh! Lonnie Johnson's Super Soaking Stream of Inventions by Chris Barton (trade book)	Obtaining, evaluating, and communicating information, focused on engineering core ideas and practices Engaging in engineering design
	The Balloon Rocket Story (researcher-designed text)	Engaging in a second-hand investigation Designing and conducting first-hand investigations
Unit 3: How can we help the birds	Secrets of the Snowy Owl (popular press video)	Obtaining, evaluating, and communicating information, focused on core ideas related

around here grow up and thrive?		to bird migration and the practice of designing and conducting investigations
	Snowy Owl Data Table (researcher-designed text)	Analyzing and interpreting data to make an evidence-based claim
Unit 4: How can we grow plants for food in our community?	In the Garden with Dr. Carver by Susan Grigsby (trade book)	Designing and conducting a first-hand investigation
	Ms. Ollie's Plant Investigation (researcher-designed text)	Engaging in a second-hand investigation

Once I selected each focal text, using the criteria described above, I began the process of preparing and analyzing observation data. First, I used the enactment timeline (described previously) to identify the focal lessons in which the selected texts and related tasks were enacted. Once these lessons were identified, I reviewed my (or another MLs researcher's, for times I could not be in class) qualitative field notes and viewed and transcribed all video records of each lesson's enactment. Depending on the text and task, this ranged from one to four days of videoed instruction for each lesson. Across the four instructional units, I reviewed and transcribed classroom video data for a total of 19 days of MLs project-based science instruction.

In addition to transcribing all audible student and teacher talk, I also embedded notes within their transcribed talk about the curriculum resources in use (e.g., texts, student process sheets, PowerPoint slides, investigation materials) and the activity in which members of the class were engaged as I viewed the videos of instruction. The teacher wore a high-quality remote microphone, which transferred audio directly to the video recorder. The remote microphone also clearly captured most student voices during whole-class conversations and small group discussions in which the teacher was involved. Occasionally, students' contributions were inaudible on the video recordings, and were marked as such in the transcripts. In these cases, I cross-checked with field notes and backup audio recordings when these were available.

Once I transcribed all lesson videos, in which a focal text(s) and related task(s) were enacted, I transferred the written transcript into a table within a Microsoft Word document, placing each turn of talk into a separate row. To the right of the column containing the raw transcript data, I added a column labeled "Notes/Codes." I began my analysis by reading through the lesson enactment transcript line-by-line (Dyson & Genishi, 2005). I then began the process of open coding the transcript content (Corbin & Strauss, 2007), during which I jotted down notes, comments, and questions in the right-hand column that seemed relevant to my research questions. Recording these initial notes and comments allowed me to begin examining the data with the aim of uncovering evidence of the ways in which MLs instructional events, focused on the use of texts and related tasks, unfolded in the focal classroom (Bogdan & Bilken, 2007). For instance, many of my initial notes and comments focused on (a) noting the ways in which the teacher and her students engaged with and around the designed texts and tasks in the context of MLs instruction, (b) the designed and enacted opportunities for students to build knowledge and to develop and use foundational and scientific literacies, and (c) evidence of the ways in which the students and their teacher took up these opportunities within the lessons. Based on the content of my research questions, I noted talk and activity which seemed related to opportunities or evidence of (a) science learning/knowledge-building, (b) development and use of foundational literacies, and (c) development and use of scientific literacies and/or (d) engagement in scientific practices. During the open coding phase of my analysis, my notes and codes frequently repeated the exact words of the students and their teacher, as well as noting relevant concepts from the literature (Merriam, 2009). Thus, my analysis was both inductive and deductive during this phase (Stake, 1995). Table 3.6 provides an excerpt from my initial open coding of enactment transcripts from Unit 2.

T	Our nose, alright? So, we use--what are all of those things called?	**What is an observation?**
S	Senses.	
S	Five senses.	
T	Our senses, okay? So, when we make observations, we look at our data. And maybe I should call them noticings. Do we notice anything about our data? Sitting up please. Do we notice anything about the data we collected? If you're not looking at the data, you're not going to be able to make any noticings. But if you look at the data, you might be able to notice something about it. Emma, is there anything that you notice about the data we collected?	**Analyzing data; what do you notice?**
I	For the twine, the--it didn't go that far. It mostly stayed the same.	S noticing, data analysis
T	So I hear--	
N	So the last one was--	S noticing
T	--I hear two--	
N	--a little bit higher. Higher.	S noticing
T	I hear two noticings. Didn't go very far (writing notes on the white board), and the word very is kind of an opinionated--opinion word, but that's okay. It didn't--can we say it didn't go—	**Summarizes S noticings**
N	Far	S noticing
I	As far as everything else.	S noticing
T	Okay. It didn't go--	
S	Very far.	S noticing
T	--as far, very far--you don't have to write any of this down right now, okay? And you also said that it what? Oh, almost all of the distances for twine were what, Emma?	**Asking for clarification**

Figure 3.2. Screenshot of initial open coding of transcripts from Unit 2.

Following the initial open coding phase, I began the process of seeking patterns in my data, or category construction (Merriam, 2009). After working through the lesson enactment transcripts for a particular lesson or set of lessons that featured a focal text, I went back over my open coding jottings and comments in the "Notes/Codes" column of my table, and identified patterns that spanned multiple individual examples (e.g., engaging in scientific practices, using reading strategies, tacking between text and first-hand experience, building vocabulary, leveraging prior knowledge, using evidence from text, etc.). Consistent with Dyson and Genishi's (2005) approach to case study research, through the process of moving from open coding to category construction (making notes about relevant bits of data and then identifying patterns in the codes to construct categories), I began to develop "the vocabulary needed to tell the story (or multiple stories) of what was happening" in my case (p. 84). In this dissertation study, I analyzed each text-task enactment event separately in order to tell multiple stories of what happened within and across instructional events. Each of these "stories" is reported in my findings chapters. Figure 3.3 provides an excerpt from a table created during the analytical coding or category construction phases of my analysis of video transcript data from Unit 1.

Made connections to or engaged students in scientific practices (e.g., evidence to support claims, modeling)	
Day 1 – Claim & Evidence During	T – *If you think that the squirrel's tail is important, you are right again. The squirrel's tail helps it to keep it's…* Students – *Balance!* T – *Balance.* Now, we talked about thinking that a squirrel used its tail for balance. Did we just find some evidence that proves that? Students – Yeah. T – We did. We found evidence to support our claim that a squirrel uses its tail to balance.
Day 1 – Observe During	T – *To find out about the last features that help squirrels to climb down the tree headfirst, look closely at the back feet of the squirrels in these photographs.* Okay, you've got it right in front of you, so you don't have to look up there. Now, you should be on those two pictures. And they're telling you to look closely at what? K – The pictures! Student – The squirrels. Student – The feet. Student – The back feet. T – The back feet. They're specifically telling you to look closely at the back feet. Does anyone notice anything about the back feet? This was just as fascinating to me this summer! What did you notice about those back feet, J? J – I noticed that the tree one (the photograph of the squirrel on the tree) is actually like hanging upside down on the tree and the other claws are just leaning on it.
Day 1 – Observe During	T - What is unique about the squirrel's back feet? Malik, what's unique about their back feet? Malik – It helps them. I forgot. T – That's okay. We can come back to you…Zayn? … Zayn – There's like a little line right there, and its little claws are in there, and his feet are holding on. T – There's a little line there. His claws are hanging on while he's eating a nut. Look specifically at that picture of the squirrel that's climbing down the tree. What do you notice about its feet? C, what do you notice? Carter – That its back feet are pushing off. T – Okay, it's back feet are pushing off. What else do you notice about him, Anthony? Aiden – That, I notice that it's not exactly hanging down. It's actually using its back feet to push off and using its front feet also to push off.

Figure 3.3. Screenshot of table created during category construction for Unit 1 analyses.

While open and analytic coding were important components of my analysis and for transforming my enactment transcript data into assertions, or findings, that addressed my research questions, I did not rely on this analytic strategy alone. In addition, I combined the coding and category construction process with what Stake (1995) has called *direct* *interpretation*. Case study research relies on both data aggregation (i.e., coding) and direct interpretation of data. Creswell and Poth (2018) defined direct interpretation as drawing meaning from single episodes without identifying and analyzing multiple instances: “It is a process of pulling the data apart and putting them back together in more meaningful ways” (p. 206). By analyzing individual episodes within transcript data in this fashion, I was able to uncover the ways in which the focal lessons unfolded – specific to the design and enactment of texts and tasks, and the ways in which students took up these opportunities – in order to develop assertions that were responsive to my research questions and construct my case study report. In these instances, I analyzed individual episodes by identifying evidence of the ways in which the teacher enacted the designed texts and tasks to create opportunities for science and literacy learning, as well as the ways in which students took up these opportunities.

Direct interpretation of data is similar to *connecting strategies*, which Maxwell (2013) defined as follows: “Instead of fracturing the initial text into discrete segments and resorting it into categories, connecting analysis attempts to understand the data…*in context*...to identify the relationships among the different elements of the text” (p. 112). Thus, in addition to sorting my data into categories, separate from context, I approached classroom transcript data holistically, in order to identify relationships that connected text-reading and related task instructional events and activity, in the focal classroom, into a coherent whole. In the process of reviewing the raw transcript data, as well as my initial “Notes/Codes,” I teased out the various teacher and student moves that revealed opportunities for – and evidence of – students’ knowledge-building, and their use and development of foundational and scientific literacies in order to develop assertions that were responsive to my research questions.

Because I conducted my primary analyses *within* instructional events, while certain patterns *did* emerge during the coding process, I found that other instructional episodes within focal lessons were responsive to my research questions in their own right. Aligned with Stake's (1995) argument that "even with instrumental case study, some important features appear only once," (p. 75) my use of direct interpretation in combination with open and analytic coding was important for identifying and analyzing events within focal instructional episodes, particularly in instances in which I found significant meaning in a single episode. Through *direct interpretation*, I analyzed single episodes within focal lessons that seemed important for uncovering the ways in which the design of texts and tasks, and the teacher's enactment, created opportunities for learning and supported students' knowledge building and literacy development.

Finally, my use of direct interpretation and connecting strategies supported my construction of narrative summaries for my case study report, in which I sought to maintain both the context and story of the ways in which instruction unfolded in the classroom during focal lessons (Maxwell, 2013). In the narrative summaries that I constructed, I leverage extended quotes from transcribed classroom video data, but reorganized the data in order to provide a succinct account of the relationships among the designed written curriculum materials, the teacher's instruction, and students' activity and learning. By combining direct interpretation, connecting strategies, and coding, I report assertions that emerged from identified patterns in the data as well as from single, and connected, instructional episodes that were imperative for responding to my research questions.

Analysis of interviews. Following the development of an enactment timeline for the full year of MLs instruction in Ms. Lane's class, I began the process of preparing and analyzing focal student and teacher interview data. I began by transcribing the audio recordings of all sixteen interviews that I conducted with focal students following the enactment of the first MLs unit of instruction. After transcribing all interviews within a single Microsoft Word document, I began my analysis by reading through the first interview transcript line-by-line (Dyson & Genishi, 2005). As I read each transcript, my first analytic step was to transfer the raw transcript data into an Excel document, which allowed me to break the interview transcripts into smaller “chunks” specific to interview question. The first column of this Excel document contained a list of the focal students’ names, and the first row consisted of the questions from the interview protocol. Reorganizing the interview data in this way was an important step toward analyzing the content of students’ responses to interview questions, both across questions for individual students, and across students for each question.

I drew on multiple approaches for analyzing interviews. To analyze some interview questions, I engaged in open coding and category construction. To do this, I first prepared my interview data for open coding responses to each interview question, moving all students’ responses to a single interview question into a dedicated table in a Microsoft word document, to which I added a column to the right of the raw transcript excerpts labeled “Notes/Codes.” As I read through each transcript excerpt during open coding (Corbin & Strauss, 2007), I jotted down notes, comments, and questions in the right-hand column specific to the content of students’ interview responses that seemed relevant and responsive to the related interview question. These initial notes often repeated students’ exact words from their interview responses. In Figure 3.4, I provide an example of initial open coding of students’ responses to an interview question from Unit 1.

Which text did you read? What do you remember about that text?		
Aiden	A – The **garter snake**. M – You read about the garter snake? What do you remember about that text? A – That it has a **detachable jaw** that can pretty much open at any height and I…and it can eat like…a fish. It can eat a fish easily. M – Oh my. A – It can eat a fish that came out of the water easily. M – Interesting. Anything else? A – That it also has a…that it also **uses its tongue** to smell the air before it tries to get its prey…and I forgot the other structure that it has… Oh and did you know that the squirrel eats garter snakes and a garter snake eats a squirrel? M – Oh, that's very interesting. A – And sometimes it will eat small little birds, like small baby birds.	Garter snake Jaw to eat prey Tongue to smell air and catch prey Predator/prey relationships
Brandon	M – Which one? How do the **red-tailed hawks** survive in their environment? B – Uh-huh M – Excellent! What do you remember about the text? B – His **beak** is like umm…it's like umm sharp. It's really sharp. His **claws** umm…they pick up the prey.	Red-tailed hawk Beak and claws to pick up prey
Carter	C – **Earthworms**! M – Earthworms? What do you remember about that text or about earthworms? C – The earthworms have **mucus** around their body to move through the soil. M – Anything else? C – Earthworms mostly eat dead stuff. M – Okay, very interesting. C – Umm…earthworms' **predators** are birds. M – Okay. C – 'Cause the birds eat them.	Earthworms Mucus for moving through soil Predator/prey relationships
Christian	C – **Eastern garter snakes**. M – Eastern garter snakes. What do you remember about that text? C – That squirrels and eastern garter snakes, they do **attack** each other. M – Anything else? No? Wonderful. C – Yeah. M – Oh, you remember something else? Excellent, what did you remember? C – That the can detach their **jaw** so they can eat their prey whole.	Garter snake Jaw to eat prey whole Predator/prey relationships

Figure 3.4. Screenshot of initial open coding of a student interviews from Unit 1.

After the open coding phase, I began to construct categories by identifying patterns in the interview data across student interviews. Merriam (2009) defined a category as "the same as a theme, a pattern, a finding, or an answer to a research question." After working through the sorted transcripts of the focal students' interview responses, I went back over my open coding jottings and comments in the "Notes/Codes" columns of my tables and grouped related codes as I identified patterns that spanned multiple individual examples. Corbin and Straus (2007) refer to this phase of data analysis as *axial* or *analytic coding*. In Figures 3.3 and 3.4, below, I provide screenshots of two types of tables I created during category construction, or analytic coding, of student interview data.

How did students answer: *How was this helpful to your learning?*		Friction	Building	Fair Tests
Jenna				
Brandon	…it helped me learn about how if I wanted to build one that I can know if I…if I could build one.			
Carter	Umm most of our class knows about it because we did it in technology and our group finished it so we know most about it, how it moves and we know most of about the thing that they made.			
Julia				
Leon	Umm it helped us learn how the balloon rocket moves...moves and it helped...and it helps us learn more how to build...to build balloon rockets and that's it.			
Malik	How to build a balloon rocket out of balloons.			
Nick	Umm that the more friction there is, the less that it go…the umm least that it goes.			
Owen	Fair tests and why we shouldn't umm…and umm…and about making fair tests are better than non fair tests.			
Zayn				
Keyanta	Well, we read it and then we did it. We showed Jamal that this works a different way. We can do it string and yellow string. Yeah.			
Lucas	It helped us learn about making toys. So we did this to help us with the friction. It helped us a lot because without this text we wouldn't know because they asked…the aunt and the aunt told them about to imagine something and without that part you wouldn't know about the friction… So she said that it was all…it was all just like…all like asphalt or concrete and they couldn't push it if it was asphalt they could that would be at least easier because brand new asphalt is like really smooth… but as it gets older and been there for a long time, it gets more dirty. But he imagined if ice was instead would be on there you could push it.			
Aiden	Biographical engineering…			
Christian	How you could try different ways to make a water balloon work.			

Figure 3.5. Screenshot of interview analysis during category construction from Unit 2.

Interview Question: How did reading about Lonnie Johnson help you understand more about what engineers do?

Category: By providing an example of how engineers design solutions (e.g., information about how Lonnie Johnson designed the Super Soaker)
Aiden Well, it helped a lot because for one, it helped a lot because it actually gave us a lot of data on what happened in 1991 when someone, Lonnie George Johnson, created the super soaker…
Brandon …he came up with a good idea and then he made what he wanted, what was in his mind.
Christian How they make stuff that kids don't know about yet.
Carter …engineers keep on creating stuff that makes, then create more.
Lucas They told us that scientists can, that scientists can make stuff on accident.
Leon Because it helps you learn more, it helps you learn more about how toys, how toys get built and how they get sent to stores.
Makayla That he worked on lots of things to help people.
Owen That they usually improve stuff and they make, they never stop making stuff.
Raven It helped me understand more about what engineers do by like when it told us like how he like, like how they invent things and like how like if they have patents like no one else can take what they're doing and copy off of them.
Zayn That if you take it (your design solution) somewhere, they don't always agree with you (people don't always provide positive feedback on designs)

Figure 3.6. Screenshot of interview analysis during category construction from Unit 2 Lonnie Johnson texts.

In addition to engaging in open and analytic coding to analyze some interview questions, I also analyzed the content of student interviews, particularly for Units 1 and 4, in order to identify and describe the frequency with which focal students identified particular texts as those from which they learned the most from, that were most interesting, or that were most important for their teacher to use when teaching the unit with future students. These analyses enabled my identification of patterns related to students' texts preferences and the reasoning that students provided for these choices. I then developed summary statements of these findings to support my synthesis. Figure 3.7, below, provides an example of one of these summary statements based on my analysis of Unit 4 student interviews.

Grade 3 Unit 4 Interview Summary

Learning
5 of 16 focal students identified In the Garden with Dr. Carver as one of the two texts in the unit that they learned the most from.

4 of 16 focal students identified Ms. Ollie's Plant Investigation as one of the two texts in the unit that they learned the most from.

Interesting
6 of 16 focal students identified In the Garden with Dr. Carver as one of the two most interesting texts in the unit.

5 of 16 focal students identified Ms. Ollie's Plant Investigation as one of the two most interesting texts in the unit.

Keep
6 of 16 focal students identified In the Garden with Dr. Carver as one of the texts their teacher should keep if she could only keep two the following year.

6 of 16 focal students identified Ms. Ollie's Plant Investigation as one of the texts their teacher should keep if she could only keep two the following year.

Skip
9 of 16 focal students indicated that their teacher should not skip any of the texts the following year.

One focal student indicated that his teacher should skip Ms. Ollie's Plant Investigation the following year because, "We already like did this, so what would be the important thing if we already learned about these? …We already did our mung beans."

Figure 3.7. Screenshot of summary statements based on analyses of Unit 4 student interviews.

I also transcribed audio recordings of my interviews with the teacher and engaged in coding in a similar fashion. I primarily drew on teacher interview data as a source of triangulation (Merriam, 2009), comparing and cross-checking Ms. Lane's interview responses with data from student interviews and observational data.

Analyzing student interview data was an important step in my data analysis, due to the role that the interview findings played in my selection of text-reading and related task events that I identified for close analysis, using observational and artifact data. Student interview data was particularly helpful in the selection of focal texts and their enactment for Units 1 and 4, in which I asked students to identify which text they learned the most from, which was the most interesting, and which one (or two) their teacher should keep to use with future students and why.

Analysis of artifacts. I identified class- and student-generated artifacts for analysis that were created in the context of focal lessons. All artifacts of focal students were uploaded and organized in the M+Box folder described previously. Hard copies of the artifacts produced by other students in the class were collected, organized, and stored in a locked file cabinet in the School of Education. Focal artifacts included class and student work such as written scientific explanations, individually- and collaboratively-developed scientific models, student process sheets, students' labeled drawings, students' typed responses to text-embedded prompts, and teacher-written notes or records of whole-class discussions related to planning first-hand investigations. While I collected all students' artifacts, I only drew on the artifacts developed by the sixteen focal students for close analysis.

I primarily used artifact data as sources of triangulation, by cross-referencing with enactment data in order to discover "a converging line of inquiry" (Yin, 1994, p. 92). To this end, I analyzed the content of student- and class-generated artifacts in a variety of ways depending on the details of a particular artifact. For instance, in my first findings chapter

(Chapter IV), I analyzed the content of individual students' models for evidence of the ways and extent to which students' incorporated text-based evidence introduced in the reading and emphasized in class discussion. In my third findings chapter (Chapter VI), I analyzed students' written responses to a series of prompts for evidence that they applied skills, previously used in whole-class contexts, to tasks later completed individually or with a partner. In sum, student- and class-generated artifacts provided evidence of the ways in which students' incorporated ideas from text in student- and class-generated products, and insight into students' foundational and scientific literacy development.

The Utility of Pairing Design-based and Case Study Research Methods

As introduced previously, in this study, I used design-based and case study methods to respond to my research questions. Two overlapping strengths of design-based research are the method's potential to address issues relevant to practitioners and to inform instruction in other settings. Reinking and Bradley (2008) compared DBR with experimental and naturalistic research by suggesting that while naturalistic research asks: *What is?*, and experimental research asks: *What is best most of the time?,* DBR sets its sights on improving practice by asking: *What could be?* In other words, DBR approaches address a long-standing need in educational research to align educational theory, research, and practice in order to make recommendations to practitioners that are meaningful, concrete, and directly applicable in the classroom. The aim of the present study, designed and conducted within a larger design-based research project, was to investigate, uncover, and improve the design of texts, related tasks, and curriculum materials that support their use, through the close study of their enactment in the context of one third-grade classroom.

Building on Reinking and Bradley's (2008) comparison of naturalistic and design-based research methods, I argue that it is important to understand "what is" in order to better conjecture and thus, design for, "what could be." Indeed, this is well-aligned to DBR's iterative approach to intervention design and implementation. To this end, I combine design-based and case study research methods in the present study, in order to both understand the unfolding of a designed instructional intervention, *Multiple Literacies in Project-based Learning*, in one third-grade classroom – with a particular focus on the design and use of texts and related tasks designed for the curriculum – and to improve the materials in order to better serve their designed purpose in the context of the larger PBL intervention. As described previously, I used conjecture mapping (Sandoval, 2014), to identify theoretically salient features of the design of the instructional intervention, specific to literacy integration, and iteratively mapped how these features are predicted to work together to produce specific outcomes. The development of conjecture maps guided my data collection, analysis, and case study construction.

Case study research, an interpretivist methodology, aligns well with the sociocultural perspective that I bring to this work. In this study, I posed a question about a teacher and her students as they engaged in a particular instructional intervention in one third-grade classroom. Thus, this is a single-case research study. Similar to claims made about the utility of design-based research, Stake explained that "the utility of case research to practitioners and policy makers is in its extension of experience" (1995, p. 245). Although case studies cannot make claims about causal relationships among teaching practices and student learning, Dyson (1995) described the usefulness of case studies for illustrating "dimensions and dynamics of classroom living and learning" (p. 51). In other words, case studies have the potential to provide readers with a sense of "having been there," but as seen through the researcher's eyes, inviting readers to view familiar situations and settings through a new lens (Donmoyer, 1990).

Minimizing Threats to Validity

Throughout the design and conduct of my dissertation study, I used a number of strategies to strengthen the credibility, or validity, of my findings. First, to enhance the internal validity of my study, I engaged in triangulation, using multiple sources of data and methods of analysis (Merriam, 2009). For instance, I collected and analyzed observational data in the form of qualitative field notes, and transcribed video records of enacted lessons. I also collected and analyzed semi-structured student and teacher interviews as well as class- and student-generated artifacts. Triangulation, using these multiple sources of data, consisted of cross-checking and comparing the data I collected in order to confirm or disconfirm emerging findings.

Another strategy for enhancing validity in qualitative research is by spending adequate time in the field (Merriam, 2009). Recall that, while I selected focal texts and lessons for close analysis and reporting findings, I observed and collected data in the focal classroom for 120 of the 130 hours during which the teacher enacted the *Multiple Literacies in Project-based Learning Intervention*. This extended time in the field allowed me to uncover and understand the ways in which the enactment of the curriculum unfolded in the focal classroom and to get as close as possible to understanding the students' and their teacher's experiences and perspectives as they engaged in the use of the designed texts and related tasks included in the curriculum.

In addition to triangulation and adequate time spent collecting data, during my analyses, I made intentional efforts to search for disconfirming evidence and to seek data that supported alternative explanations (Patton, 2002). Related to this process, in each findings chapter, I unpack limitations of the design and enactment of texts and tasks that were revealed in my analyses and describe ways in which these limitations might inform revisions to improve the design of the intervention in general, and to curriculum materials specifically (e.g., texts, materials designed to support text use).

Further, I created an "audit trail," illustrating how I made decisions and arrived at my results throughout my inquiry by describing my approaches and processes for data preparation and analysis (Lincoln & Guba, 1985). Merriam (2009) explained that, "just as an auditor authenticates the accounts of a business, independent researchers can authenticate the findings of a study by following the trail of a researcher" (p. 222). Earlier in this chapter, I described in detail, my approaches to data collections, decision making, and analysis, throughout the design and conduct of my study. Similarly, I have worked to create what Yin (1994) called a "chain of evidence" so that the reader can follow my data collection and analysis. I began this work in the current chapter. Additionally, I continue to build this "chain of evidence," by presenting my findings and the evidence that supports them in a linear fashion across text-reading and related task events, both within and across chapters.

Finally, throughout the reporting of my research, I strove to provide a highly detailed or thick description of my findings. In my findings chapters, I support this thick description with excerpts of raw data from transcripts of lesson enactment, artifacts, and interviews so that the reader may assess the evidence upon which my assertions are based. As Merriam (2009) explained, this sort of detailed description paired with examples from the data is important, not only for enabling the reader to experience the study's context, but also for allowing the reader to evaluate the researcher's analysis and interpretations.

CHAPTER IV: UNIT ONE

Why do we see so many squirrels but no stegosauruses?

The instructional context for this chapter is the first *Using Multiple Literacies in Project-based Learning (MLs)* unit of instruction focused on disciplinary core ideas related to interdependent relationships in ecosystems, including organisms' needs and structure-function relationships, and climate. The unit is framed by the following driving question: *Why do we see so many squirrels but no stegosauruses?* In the unit, students work to explain how the squirrels that they can observe, around students' homes and schools, meet squirrels' needs for survival and interact with other organisms in the environment. Concurrently, students work to explain how stegosauruses survived in prehistoric environments but are no longer found today. Throughout the unit, students have opportunities to read and interpret a variety of text types, such as informational and biographical texts, as well as charts and tables.

In the first part of this chapter, I focus on the design and enactment of a researcher-designed informational text from this unit about structures that enable squirrels to climb up and down trees entitled, *For Squirrels, It's Headfirst and Down!* In the focal classroom, this researcher-designed text was paired with a video clip that further illustrated the ideas in the text. Together, these resources were designed to build upon students' firsthand observations of squirrels around their school, and to support students to draw a scientific model and explain how squirrels survive in their habitat. The learning goal for the lesson was the following: *Students will develop a model that the squirrel's structures are related to its survival in its environment and that a scientist can tell things about an organism's environment by looking at its structure.*

In the second part of this chapter, I focus on the design and enactment of a set of researcher-designed texts, which we called *Structure-Function Cards*, each of which provided information about an organism (plant or animal) that lives in similar environments to the Eastern Gray Squirrel's. The learning goals for these lessons were the following: *(1) Students will engage in text about other organisms that are a part of the squirrel's environment, including how they all interact and survive in different ways; and (2) Students will communicate information from texts about other organisms that are part of the squirrel's environment, how they all interact and survive, meeting their needs in different ways.*

The Unit of Instruction

In this section, I describe the progression of the PBL unit leading up to the use of the focal texts, in order to situate these text-reading events within the larger unit of instruction. Following the introduction of the unit driving question, students began the unit by viewing a brief video clip of organisms (both plants and animals) that lived during the Jurassic era and identifying similarities and differences between the organisms in the video and organisms that the students observe around their homes and school. Students then engaged in fieldwork to observe squirrels and other organisms in their habitats. Because there were few squirrels to observe near the focal school, the students made observations of squirrels using a number of online videos.

After making and recording several observations of squirrels, students were introduced to the practice of scientific modeling, and worked together to plan and develop models to explain how squirrels survive in their habitats. In science, models are developed and used to represent a system under investigation, to ask questions and develop explanations, to make predictions, and to communicate ideas (NGSS Lead States, 2013, Appendix F). Because this was students' initial experience developing models, their models took the form of concrete drawings of squirrels in a particular environment, as an introduction to this scientific practice (NRC, 2012a). After creating their initial models, students participated in a jigsaw (Aronson, 1978), in which they selected a text about squirrel survival (e.g., escaping predators, finding food, raising young, surviving winter), and used new evidence from the text to add to or revise their initial models.

In the next set of lessons, students investigated squirrels' structures, including their teeth and jaws, by observing squirrels in photographs and videos and by conducting first-hand examinations of a squirrel's skull. Students then compared photographs of squirrel and human skeletons and conducted investigations to collect and analyze data in order to determine whether the students could balance and jump as well and as far as squirrels. At this point in the unit, the teacher engaged the class in an interactive read aloud of the text, *For Squirrels, It's Headfirst and Down,* which was designed to introduce and describe structures that enable squirrels to climb both up and headfirst down trees. The researcher-designed text was paired with a short video that further illustrated the ideas in the text. Together, these texts were designed to inform students' next round revisions to their models explaining how squirrels survive in their environment.

Finally, in the next set of lessons, students explored structure-function relationships of other organisms that live in the same environment as the Eastern Grey Squirrel, and how these organisms interact with one another in the environment. To explore structure-function relationships and to make claims about interdependent relationships among organisms, students selected one text from a set of researcher-designed texts, which we called *Structure-Function Cards*. Each of these cards provided information about one organism (plant or animal) that lives in similar environments to the Eastern Gray Squirrel's (e.g., ant, coyote, earthworm, rabbit, snake, spider, oak tree, etc.). In small groups, students read about their selected organism, noted structures that enable the organism to survive, and identified ways in which the organism interacts with other organisms in its habitat. The students then used the information in these texts to develop a second model, as a class, to explain interactions among organisms in an ecosystem.

PART I: For Squirrels, It's Headfirst and Down

In this section, I focus on the design and use of a researcher-designed informational text, *For Squirrels, It's Headfirst and Down!* This text focuses on core ideas related to adaptations that enable organisms to survive in a particular environment and was paired with a video selected to further illustrate the ideas in the text. First, I describe the design features of the text and task, and then describe the enactment. To address my research questions, I (a) describe the ways in which the design and enactment of the text, *For Squirrels, It's Headfirst and Down* (Appendix A), and task supported students' science and literacy learning; and (b) identify modifications to the design of the text and task that might enhance students' science and literacy learning, in the context of project-based science instruction.

Design of the Text: For Squirrels, It's Headfirst and Down

For Squirrels, It's Headfirst and Down was designed to: (a) illustrate core ideas related to adaptations that enable organisms to survive in a particular environment, (b) provide information that connected to and built upon students' first-hand observations and shared knowledge, and (c) motivate and provide new information to support students' engagement in the practice of scientific modeling – to revise or add to their scientific model that explained how squirrels survive in a particular environment – based on new learning.

For Squirrels, It's Headfirst and Down begins with a photograph of a squirrel climbing headfirst down a tree, followed by a series of questions: *Have you ever seen a squirrel climbing* *down a tree like the one in the photograph? How does a squirrel's body help it do that? Squirrels have special features or structures that allow them to climb down trees headfirst. What do you think those structures are?* The text, then, transitions into introducing and describing the climbing functions of four body structures (e.g., claws, tail, arms and legs, anklebone), complemented by photographs that illustrate each structure described. Finally, the text concludes with a brief summary of the structures described (See Appendix A).

As noted above, the paired video was selected to further illustrate the ideas in the text and to provide an opportunity for students to observe a squirrel using the structures they read about to climb up and headfirst down trees.

Overview of Enactment

Prior to reading the text, *For Squirrels, It's Headfirst and Down*, the teacher made connections to students' prior learning and experiences in the unit of instruction, explained how the class would participate in the interactive read-aloud, and previewed the scientific modeling task that would follow. The teacher then engaged students in the interactive read-aloud, pausing frequently to ask questions and to discuss the information in the written text and photographs. After reading and talking about the text, the teacher engaged students in discussing and listing the ideas in the text that they could use to revise their models in order to explain how squirrels' structures help them to survive in a particular environment. As students began making model revisions, the teacher conferred with individuals and small groups about how they could incorporate text information and communicate it clearly.

On the second day of enactment, the teacher and students briefly reviewed the reading and then viewed a brief video clip, depicting a squirrel climbing up and headfirst down trees, which further illustrated the ideas in the text. Next, the teacher projected one students' model, as an example, and invited the class to interpret the model and to provide suggestions for improvement. After discussing the projected model, students returned to their own models to continue their revisions. The teacher conferred with students about their revisions, scaffolding students use of information from the text to revised their models. Finally, the teacher concluded the lesson by allowing volunteers to share and explain their revisions with the class. Table 4.1 provides additional information about the two days of enactment.

Table 4.1

For Squirrels, It's Headfirst and Down and Modeling Enactment Timeline

Lesson	Day	Lesson Activities
Lesson 2.5: How do the squirrel's features help it meet its needs and survive in its environment?	Day 1 45 mins.	• Students access, *For Squirrel's, It's Headfirst and Down*, digitally, using Chromebooks • Teacher sets the purpose for reading and engages students in an interactive read-aloud of the text • After reading, teacher and students summarize squirrel structures introduced in the reading and list the structures on the board • Students begin to add to and revise squirrel environment models based on information in the text, as the teacher conferred with individual and small groups of students
	Day 2 60 mins.	• Teacher and students summarize reading and discuss learning from previous day • Students view and discuss video that illustrates ideas introduced in the reading • Teacher projects one students' model and invites the class to interpret the model and provide feedback for improvement • Students continue adding to and revising squirrel environment models, based on information in the text, as teacher confers with individual and small groups of students • Teacher projects student models for class to give and receive feedback

Testing Conjectures

In analyzing and reporting data specific to the design and enactment of *For Squirrels, It's Headfirst and Down* and modeling task, I foreground the following features of the designed MLs learning environment (i.e., *embodiment*): (a) the designed tools and materials, including teacher supports (i.e., lesson plans), student notebooks, and multimodal literacy resources (i.e., researcher-designed text, video); and (b) the task structure. The *mediating processes* outlined in my conjecture map served as analytic lenses, guiding my analyses of enactment data, artifacts, and interviews. For instance, to understand whether and how *mediating processes* produced *desired outcomes* within this lesson, I drew on transcript and individual student artifact data (i.e., squirrel survival models) in order to closely analyze the ways in which the *mediating processes* emerged and unfolded in the classroom.

As Sandoval (2014) argued, "In learning environments, the *use* (emphasis mine) of particular tools for specific tasks enacted in specific ways is intended to produce certain kinds of activity and interaction that are hypothesized to produce intended outcomes." Thus, the close analysis of transcribed video of lesson enactment allowed me to analyze the ways in which the designed tools and materials (e.g., teacher supports, literacy resources) and task structure produced observable interactions: (a) using tools of reading, writing, viewing, and discussing for meaningful purposes, (b) using scientific ideas and practices, (c) building on prior knowledge and funds of knowledge, and (d) the teacher's instructional moves. Analyzing observable interactions revealed within transcript data, in combination with student-generated artifacts and interview data, allowed me to examine whether and how the *mediating processes* led to the *desired outcomes*, including: (a) making sense of and synthesizing multimodal texts, (b) using science ideas and practices to make sense of and explain phenomena, and (c) developing increasingly sophisticated written and visual artifacts. I present my findings in the following section.

Findings

In this section, I present findings from my analyses of enactment data (lesson plans, field notes, transcribed video recordings, and student artifacts) and interview data with focal students and their teacher to respond to my research questions: (1) How did the design and enactment of

For Squirrels, It's Headfirst and Down and task support third-graders' science and literacy learning? (2) How might modifications to the design of the text and task better support third-graders' science and literacy learning, in the context of project-based science instruction?

Findings from enactment. I found that the design of the text and tasks, and the teacher's enactment of *For Squirrels, It's Headfirst and Down*, synergistically supported third-graders' science and literacy learning. I also identified missed opportunities, both within the design of the curriculum resources and the enactment of the lessons, for further supporting the science and literacy learning of all students.

Before reading: Setting the purpose and preparing to read. Analyses of the written curriculum and transcripts of classroom enactment revealed that the teacher leveraged the text and task, in this case, in support of students' science and literacy learning by supporting students to (a) connect to their prior knowledge and experiences, (b) focus on the purpose for reading by connecting the purpose to the task, and (c) make predictions about the text prior to reading.

Connecting to students' prior knowledge and experiences. To prepare students to read the text, *For Squirrels, It's Headfirst and Down*, the teacher began the lesson by asking students to recall their recent experiences in the PBL unit. After projecting the text on the SMART board and helping students open the text on their Chromebooks, the teacher said, "Alright, so, *For Squirrels, It's Headfirst and Down*. I want you to think and recall some of the things that we've done this week…I want you to think about what we've done for the last couple of days…So, we have been talking about adaptations…We've been talking about structures that squirrels have. We have been learning about the things that they do" (Day 1). In this excerpt, the teacher made connections to the core ideas students had been focusing on in science. While I conjecture that making these connections primed students' thinking about squirrels' structures that students investigated during previous lessons (e.g., strong hind legs for jumping, sharp teeth and strong jaw for cracking acorns and nuts, and tail for balancing), because the teacher did not invite students to share their reflections on what they learned and their experiences, I cannot be certain that all students made these connections to their prior experiences and knowledge before reading.

Specific to students' literacy learning, supporting students to activate prior knowledge before reading created opportunities for students to draw on their related knowledge and experience to interpret new information in text. Reading instruction that engages students in drawing on their prior knowledge and experiences as they read, supports comprehension (e.g., Brown, Pressley, Van Meter, & Schuder, 1996; Saunders & Goldenberg, 1999). In a related vein, but specific to students' science learning, in the example above, the teacher made explicit the core science ideas (e.g., adaptations) that students were learning about, signaling that they would continue to build knowledge related to these core ideas during this lesson.

Setting the purpose for reading. In earlier lessons, students were introduced to the scientific practice of modeling and developed initial models, based on evidence from observations, video clips, and written texts to explain how squirrels survive in particular environments. The purpose of reading *For Squirrels, It's Headfirst and Down* was to provide new evidence that students could add to their models to better explain squirrel survival. Revising models to incorporate new evidence is an important element of the practice of scientific modeling (NGSS Lead States, 2013, Appendix F). One way that the teacher supported students' science and literacy learning, in this context, was by tying the purpose for reading to the task of revising students' models.

After priming students to think about their earlier observations and investigations, in which they learned about squirrels' structures (e.g., jaw and teeth; strong hind legs) and how certain structures enable squirrels to survive, the teacher explained: “We’re going to read this together, but as we’re reading, I’m going to ask you some questions. And then we’re going to…look at our models” (Day 1). As described in the lesson plan, the purpose for reading was to use information in the text to revise students’ models, which explained how squirrels survive in their environment. This brief excerpt illustrates how the teacher connected the reading to the modeling task.

Making predictions. Another way the teacher used the text to support student learning was by engaging students in making predictions before reading.

Teacher: So, For Squirrels, It’s Headfirst and Down. Just make a prediction… What is this article going to be about? What are we going to be reading about? …Malik, what are we going to read about?

Malik: How squirrels climb down trees.

Teacher: How they do what?

Malik: How squirrels put their heads first.

Teacher: And do what? I just didn’t hear what you said.

Malik: And crawl down the tree.

In this excerpt, the teacher asked the students to make a prediction, based on the title, about what they thought they would be reading. In this case, the teacher invited Malik to share his prediction with the class. Engaging students in making predictions about the text, primed students’ thinking about what they would learn from the text.

During reading: Supporting students to read and interpret information. Analyses of the written curriculum (e.g., text and lesson plan) and transcripts of classroom enactment revealed that the teacher leveraged the text and task in support of students’ science and literacy learning by supporting students to read and interpret the information in the text. During the interactive read aloud of *For Squirrels, It's Headfirst and Down*, the teacher supported students' reading and interpretation through (a) engaging students in visualizing and acting out the ideas in the text, and (b) asking questions to check for student understanding.

Engaging students in visualizing and acting out ideas in the text. One way the teacher supported students to read and interpret the text was by prompting them to visualize important information. In one example, after reading aloud a section of the text that described how the squirrel uses its sharp claws to grip the bark of the tree ("With its sharp claws, a squirrel can grip the bark of a tree. The strong grip of the front claws allows the squirrel to hold on while it moves its back feet. Then, the back feet can hold on while the front feet move."), the teacher asked students to visualize or to "picture" the description in their mind.

Teacher: So, picture that in your mind. Remember, when you're reading, especially informational text, you want to picture, in your mind, what they are telling you. And, they've given you a picture right here. [Teacher begins rereading] "The strong grip of the front claws allows the squirrel to hold on while it moves its back feet." So, in my mind – I'm not going to do a handstand, but – my front claws are down [the teacher gestures to mimic the body position of the squirrel] and my back feet are doing what [the teacher gestures to mimic how the squirrel's feet would move]?

Students:[2] Moving.

[2] When multiple students made the same contribution, in the context of class discussion, it is denoted as "Students" within transcript excerpts.

Teacher: They are able to move. And then, if I want to look around, my back claws are going to hang onto that bark or that tree, while my front claws do what [the teacher gestures to mimic how the squirrel's feet would move]?

Kaylee: Move!

In this excerpt, the teacher paused after reading the portion of the text that described how squirrels' sharp claws enable them to climb headfirst down trees. After prompting students to picture the description in their minds, the teacher reread a portion of the text and made several motions to gesture or act out how she visualized the squirrel's movement. She followed her explanation of what she was picturing with questions to check students' understanding of the information in the text.

Asking questions to check for understanding. In addition to prompting students to visualize text information to support comprehension, the teacher paused frequently to ask questions, checking for student understanding as they read the text together. This included asking questions about the meaning of the words in the text as well as asking questions aimed at supporting students to analyze and interpret multimodal information, such as the photographs in the text. In one example, after reading about two of the squirrels' structures, the teacher paused to check for student understanding.

Teacher: And what is that structure that they just talked about that the squirrel has to help it climb headfirst and down? On the count of three, whisper-shout it. One, two, three.

Students: Claws!

Teacher: The claws, okay. Now, it mentioned something else… What else does it have, Aiden?

Aiden: Feet.

Teacher: Okay, well, it does have feet. Keyanta?

Keyanta: It said, in the last paragraph, it says its back feet.

In this excerpt, the teacher paused to review the structures introduced in the text and, for the first question, asked students to respond in the form of a "whisper-shout," so that all students had the opportunity to share their response. The teacher followed this question by asking what other structure was identified in the text. Aiden responded that the text described squirrel's feet, and Keyanta elaborated that "in the last paragraph, it says its back feet." This example illustrates one way in which the teacher paused during reading to focus students' attention on the main ideas in the text and to check for student understanding of these ideas.

As the teacher and students continued reading, as prompted by the text (e.g., "Look closely at the back feet of the squirrels in these photographs."), the teacher asked students to make and share their observations of squirrels' structures using two photographs in the text (see Figure 4.1).

Figure 4.1. Photographs students analyzed in *For Squirrels, It's Headfirst and Down*.

Teacher: [Reading aloud] "To find out about the last feature that helps squirrels to climb down the tree headfirst, look closely at the back feet of the squirrels in these photographs." Okay, so you've got it right in front of you… Now, you should be on those two pictures (see Figure 1, above), and they're telling you to look closely at what?

Kaylee: The pictures!

Student:[3] The squirrels.

Student: The feet.

Student: The back feet.

Teacher: The back feet. They're specifically telling you to look closely at the back feet. Does anyone notice anything about the back feet? This was just as fascinating to me this summer! What did you notice about those back feet, Jessica?

Jessica: I noticed that the tree one is actually like hanging upside down on the tree and the other claws are just leaning on it.

Teacher: Okay, so it's hanging upside down. If we hung upside down on a tree, could we turn our foot around and dig our toes into the tree?

Students: No.

Teacher: I mean, even just sitting in your chair, if you tried to turn your foot around and dig your toes into the ground, could you do that with both of your feet?

Students: [Some students attempt this, while sitting in their chairs.] No.

Teacher: So, what is it? What is unique about the squirrel's back feet? …Look specifically at the picture of the squirrel that's climbing down the tree. What do you notice about its feet? Cameron, what do you notice?

[3] When a single student made a contribution, in the context of class discussion, but could not be identified in video or audio recordings, it is denoted as "Student" within transcript excerpts.

Cameron: That its back feet are pushing off.

Teacher: Okay, its back feet are pushing off. What else do you notice about him, Aiden?

Aiden: That I notice that it's not exactly hanging down. It's actually using its back feet to push off and using its front feet also to push off.

Teacher: Okay…let's keep reading. Let me keep reading.

In this excerpt, as prompted in the student text, the teacher asked students to study the photographs and invited students to share their observations. After reading the instructions in the text (i.e., "…look closely at the back feet of the squirrels in these photographs."), the teacher guided students to clarify what, specifically, they should examine within the photographs (i.e., "the back feet of the squirrels."). After clarifying the task, the teacher invited multiple students to share what they noticed in the photographs before continuing to read.

After students shared what they noticed about the squirrels' back feet in the two photographs, the teacher resumed reading and then paused again, after reading the next sentence (i.e., "Did you notice that the back feet of the squirrel in the first photograph are pointing back, while the back feet in the second photograph are pointed toward the front?"). At this point, the teacher asked students to make an inference and compare the squirrels' body structure to their own structures, as humans.

Teacher: So, what does that say about a squirrel's feet? What are they able to do? …Kayla?

Kayla: Bend.

Teacher: Well, they're able to bend, yep. Carter?

Carter: Flex.

Teacher: Okay, they are able to flex how?

Carter: Their legs like make them.

Teacher: Is their whole leg like that? Malik?

Malik: It can rotate and turn.

Teacher: They can rotate and turn. Oh, say those words again, Malik!

Malik: Rotate and turn.

Teacher: Rotate and turn. You rotate something, it moves, right? …could we do that?

Students: [Some say yes and some say no.]

Teacher: Probably not. Show me how yours can rotate all the way back. Can yours rotate all the way back? [Several students stand up in the front of the classroom or at their seats and attempt to rotate their feet backward like a squirrel.] What would happen if you tried to? If you forced your foot back there, what would happen?

Ellie: You would break it.

This excerpt illustrates how the teacher paused to support students' sense-making as they used both the images and words in a text, as well as to compare the squirrels' body structures to their own, to build a shared understanding of the ideas in the text.

After reading: Using information from the text to inform revisions to scientific models. Analyses of the written curriculum (e.g., text and lesson plan) and transcripts of classroom enactment revealed that the teacher used the text and task to scaffold students' science and literacy learning by supporting students to identify and use information in the text in order to revise their scientific models in whole-class, small-group, and one-on-one contexts. In addition to this, the teacher leveraged the pairing of the text and task to scaffold students' understanding of and engagement in the scientific practice of modeling.

After reading the text, the teacher made a number of instructional moves to scaffold students' use of the information in the text to inform revisions to their models. For instance, immediately after reading the text, the teacher connected the reading to the modeling task and asked students to recall the structures, introduced in the text, that squirrels use to climb headfirst down trees.

Teacher: Alright, let me ask you this. Are there any things that you want to add…remember, our models are supposed to show how a squirrel is able to survive in its environment? What were the structures that were just mentioned in this reading? …Ellie, what was one structure?

Ellie: A special anklebone.

Teacher: Okay, an anklebone. Can we just say anklebone?

Ellie: Uh huh

Teacher: Okay, so its anklebone (the teacher begins recording a list of structures students identify on the board). What else does a squirrel have that allows it to climb headfirst down? Julia?

Julia: Claws.

In this exchange, the teacher connected the text to the modeling task by asking students to recall the structures that were introduced in the reading. In this exchange, Ellie and Julia recalled the squirrels' anklebone and claws, which the teacher recorded on the board for the class to reference as students revised their models. As this conversation continued, additional students contributed to the list of structures until all four structures from the reading were listed on the board. The co-

constructed list of structures served as an additional support for students as they began their modeling revisions.

Once students began revising, the teacher scaffolded their use of information from the text by conferring with individual students and by inviting students to share examples of their revisions with the class. For instance, upon observing one student's model, the teacher called the class back together and invited the student to share.

Teacher: Oh, Ellie's adding something. Ellie, do you want to share with us what you're adding? …Ellie, what are you adding?

Ellie: I'm adding…another squirrel in this position that it can be.

Teacher: Okay, you're adding another squirrel, and you're putting it in what kind of position? Can you describe that for me?

Ellie: In the position going down where its legs are facing backwards and its front paws are facing forward.

Teacher: …Ellie, just adding another squirrel, what else could you do in your models, once you've drawn that squirrel…what could you do, Sam?

Sam: Label.

Teacher: Label it. Label the back legs. What specifically would you label, Sam? What structure does it have on its back legs?

Sam: Claws.

Teacher: Okay, it has claws. What else does it have? Aiden?

Aiden: It has an anklebone.

Teacher: It has an anklebone, right? Those are the structures that allow it to go headfirst and down.

This excerpt illustrates how the teacher used an individual student's model to launch continued review and discussion of the four structures introduced in the reading. In science, one purpose of models is to communicate ideas to others (NGSS Lead States, 2013, Appendix F). In addition to scaffolding students' use of information from the text, this example also illustrates how the teacher used Ellie's model to introduce the idea of using labels to clearly communicate students' ideas in their models. The excerpt, above, provides one example of how the teacher scaffolded students' use of labels to clearly communicate information, or evidence, from the text in their models. This exchange prompted students to begin labeling the structures identified in the text. Figure 4.2, below, shows a screenshot of Ellie's model, in which she drew a squirrel climbing headfirst down. After this exchange, she returned to her model to add labels for the squirrel's anklebone and claws.

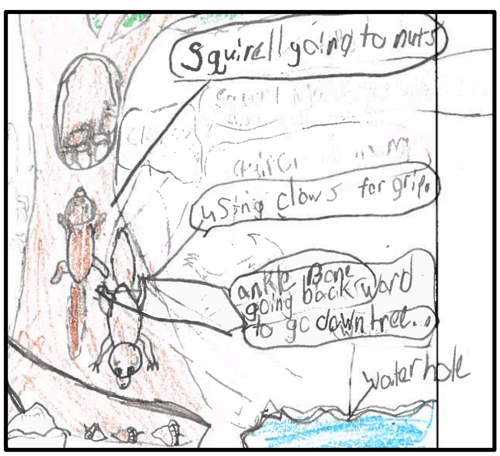

Figure 4.2. A section of Ellie's model, in which she drew a squirrel climbing headfirst down, and labeled two of the structures (anklebone and claws) described in the text.

On the second day of enactment, the teacher continued to scaffold students' use of the information in the text to inform the revisions to their models by (a) sharing and discussing additional students' models, (b) frequently directing students' attention back to the information in the text, and (c) clarifying the purpose of the modeling task.

Sharing additional examples from student models. The teacher scaffolded students' use of information in the text to inform their models by sharing additional students' models. For example, before students returned to revising their models on the second day of instruction, the teacher projected one student's model and invited the class to share what they noticed about the model and to suggest revisions.

Teacher: Does anyone see anything in Jenna's model that they have a comment or a suggestion for, because she does have a squirrel with its hind legs turned back, but I'm wondering if you have a suggestion for her? Aiden?

Aiden: What is the hole that it lives in? I can't see it.

Teacher: So, my question was let's try to focus specifically on the structures that we just discussed about the squirrel.

Aiden: Okay.

Teacher: So, what did we specifically just discuss about the squirrel, Aiden?

Aiden: How its back legs turn.

Teacher: Okay, so do you notice anything on Jenna's model that shows that?

Aiden: Yeah.

Teacher: Can you come up and point to it, please? …What might she label on there? What might she label? Ellie?

Ellie: Squirrel using special anklebone to go down the tree headfirst.

This excerpt illustrates how the teacher shared and discussed student models with the class, to scaffold students' use and clear communication of information from the text. Recall that the idea of labeling the structures from the text was introduced on Day 1. However, upon learning that not all students had taken up this idea on Day 2, the teacher pulled additional examples (i.e., Jenna's model) to revisit the structures from the reading, as well as the use of labels to clearly identify the structures. In the excerpt, above, the teacher directed Aiden to specifically focus on the structures in the text, and then asked students to suggest structures that Jenna could label in her model. Figure 4.3, below, shows a section of Jenna's model, in which she labeled the squirrel's "anklebone" following this exchange.

Figure 4.3. A section of Jenna's model, in which she labeled the squirrel "going down" and the "anklebone" after sharing her model and receiving feedback from the class.

Directing students back to the information in the text. During whole-class, small-group, and one-on-one conversations with students about model revisions, the teacher repeatedly directed students back to the information in the text: the structures that enable squirrels to climb headfirst down trees. As the teacher circulated to confer with individual students, she paused to talk with students about the revisions they made to their models.

Teacher: Can you show me what you've labeled? …Alright, show me what you did.

Malik: So, I drew a squirrel going up to the nuts.

Teacher: Okay, but what have we been specifically talking about?

Malik: A squirrel upside down using its anklebone.

Teacher: Okay, so do you have that on there and is it labeled?

Malik: No.

Teacher: So, what should you be working on right now?

This exchange provides an illustrative example of a conversation the teacher had with many students during the second day of instruction. While most students were able to recall the structures introduced in the text, many required significant scaffolding, through one-on-one conversation with the teacher, to include and clearly communicate the structures introduced in the text. I hypothesize that this task required such extensive support from the teacher for two reasons: (a) this was students' first experience developing and using scientific models, and thus, students were just beginning to understand the purposes of models, including strategies for communicating ideas clearly in their models (e.g., labeling, excluding extraneous information); and (b) this was also one of students' first forays into using evidence from informational text to support a task, such as modeling. However, despite the challenges this task presented, most students in the class incorporated and labeled one or more of the structures introduced in the reading in their revised models. Figure 4.4 shows a portion of Malik's model, in which he labeled the squirrel's "strong hind legs" and "anklebone" after his exchange with the teacher.

Figure 4.4. A section of Malik's model, in which he drew a squirrel climbing headfirst down, and labeled two of the structures (strong hind legs and anklebone) described in the text.

Clarifying the purpose of the modeling task. A final way in which the teacher scaffolded students' use of information in the text to inform their models was by making the purpose of the modeling task explicit. In science, models are used to communicate ideas to others (NGSS Lead States, 2013, Appendix F). Thus, during instruction, the teacher emphasized the utility of labeling students' models to clearly communicate ideas:

> Remember, as scientists, we want these models to explain everything that this squirrel needs in its environment. It needs those anklebones to be able to climb down those trees headfirst. The tails, the anklebones, the claws…I bet that if you went home and asked your parents, if you didn't already tell them…I'm going to guess that most of your parents wouldn't be able to name that anklebone. I'm not saying all, but I'm going to guess that most of your parents may not have studied squirrels as in-depth as you have. Now, if I let you take your models home and you had everything labeled, might they be able to figure out how a squirrel goes headfirst down?

In this excerpt, the teacher explained the purpose of engaging in the scientific practice of modeling in this lesson: "…as scientists, we want these models to explain everything that this squirrel needs in its environment." Additionally, she asked students whether others would be able to interpret their models if they had the squirrel's structures labeled, thus, scaffolding students' understanding of and engagement in the practice of scientific modeling to clearly communicate ideas to others.

In addition to emphasizing the importance of labeling to clearly communicate ideas, the teacher also emphasized the importance revising students' models to incorporate new evidence, as opposed to including fictional elements or elements that did not help students explain the system under investigation. As the teacher conferred with students and led whole-class discussions, she discovered that many students added either extraneous or "fictional" elements to their models, which she explained diminished the model's explanatory power.

> You guys are a very artistic and creative class…and I am all about your creativity. However, some of you are using that to say, "Well, I feel like putting whatever I want to in our squirrel's environment." What I'm asking you to do is to put only what a squirrel would need in its environment to survive. It doesn't necessarily need 3-10 predators. If we've got a predator, then we know it has different kinds of predators. It doesn't necessarily need a practice tree to practice going up and down and it certainly doesn't need conveyor belts. This is science, so we're really trying to focus on the specific structures the squirrel has to help it survive. If, during free time, you want to draw a fictional squirrel in a fictional environment, that has set up conveyor belts so that it doesn't have to climb up the tree to get the nuts, that's fine. I encourage that. But right now, what I'm telling you is we are drawing what is in the squirrel's environment to help it survive – what's unique to the squirrel. (Day 2, Transcript)

This excerpt illustrates one way in which the teacher scaffolded students' understanding of the purpose of developing a scientific model by making explicit their models' purpose, and how she differentiated this purpose from students' more creative pursuits (e.g., including fictional and extraneous elements). Scientific modeling was a new "genre" for students, which was made even more challenging due to the fact that students were tasked to develop their models by including evidence from multiple sources and texts (e.g., observations, investigations, videos, photographs and print texts). Despite these challenges, all students in the class developed models that included some evidence from multiple sources, although many extraneous and fictional elements remained in many students' models.

Constraints of the text and task revealed through enactment. In addition to the ways in which the text and task supported students' science and literacy learning, my analyses also revealed limitations of the design and enactment of the written curriculum. One limitation is that it is possible that the written curriculum contributed to some of the students' resistance to including only evidence-based elements in their models, as opposed to adding fictional and extraneous elements.

While most students in the class did include one or more of the squirrel's structures from the reading in their revised models, as written, the curriculum may have led to confusion about the purpose of the modeling task. When the modeling task was first introduced in the unit the lesson plan suggested that the teacher introduce students' models as telling "the story of how the squirrel survives in its environment," and to instruct students to "show everything in the model that they think is important in the survival story." Framing the modeling task in this way, as a story, may have suggested to students that the purpose of the task was to tell a narrative story about how squirrels survive, in which it would have been more appropriate to include fictional elements. Thus, it is possible that, if the model had been more explicitly introduced as a representation of a phenomenon, based on evidence, used to develop explanations and communicate science ideas to others, it is possible that students might have included fewer fictional elements. Finally, had the teacher engaged students in comparing and contrasting similarities and differences in a fictional story versus a scientific model and appropriate sources of evidence during, she might have enhanced students' understanding of and engagement in this disciplinary practice. These findings have implications for the redesign of the written curriculum.

Another limitation revealed through analysis of the written curriculum and enactment was that specific supports for engaging students in productive text-based discussion during the interactive read aloud were not included in the curriculum resources. The close study of teacher and student dialogue revealed opportunities missed to raise the level of student thinking and reasoning in the context of text-based discussion. For example, the teacher posed questions to elicit predictions prior to reading (e.g., “What is this article going to be about?” “What are we going to be reading about?”) and to activate prior knowledge (e.g., “Have you ever seen a squirrel climbing down a tree, like the one in the photograph?”). Furthermore, during reading, the teacher posed questions to check for student understanding (e.g., “So, can the squirrel move all four [feet] at the same time?” “What is unique about the squirrel’s back feet?”) and to engage students in interpreting images and words in the text (e.g., “What do you notice about its feet?” “So, what does that say about the squirrel’s feet?”). Finally, the teacher used questions after reading to elicit recall of the ideas in the text (e.g., “What were the structures that were just mentioned in this reading?”). However, across many examples, these questions did not elicit high-level thinking such as analysis, synthesis, elaboration, or evidence-based explanation, which are important for supporting student comprehension in the context of discussion (Soter et al., 2008).

In addition, neither the written curriculum nor the teacher’s enactment leveraged opportunities for students to integrate the ideas in the text with their first-hand investigations or video observations. For instance, while the teacher made connections to related unit activities (e.g., “I want you to…recall some of the things that we’ve done this week…we’ve been talking about the structures that squirrels have. We’ve been talking about what they do.”), she did not provide opportunities for students to explicitly discuss the ways in which their related observations and investigations connected to the ideas in the text. These findings reflect missed opportunities to engage students in synthesizing multiple sources and modes of information in support of sense-making, and are consistent with the findings of Arias, Palincsar, and Davis' (2015), which indicated teachers infrequently used text-based discussions to support students to integrate text ideas with first-hand investigations.

Teachers need support to engage students in productive talk about text in support of sense making. Based on these findings, during curriculum revisions, we have begun to design more and revise existing interactive reading guides (see Arias et al., 2015) to accompany the texts included in the *MLs* units, both for researcher-designed texts and for videos and trade books. These guides increasingly suggest discussion prompts and questions to engage students in high level thinking and provide the teacher with suggestions for supporting students to access prior knowledge, make intertextual connections, and explicitly integrate information from first-hand experiences, investigations, and text (Arias et al., 2015; Kucan, Hapgood, & Palincsar, 2011).

Findings from student interviews. In this section, I describe findings from interviews conducted with focal students, which provided additional insights about students' perceptions of and learning with the Unit 1 texts. The portion of the interview protocol, addressed here, consisted of a subset of questions from the larger protocol, which addressed all texts from the unit of instruction.

Specific to the text, *For Squirrels, It's Headfirst and Down*, four of the sixteen focal students identified the text as the one from which they learned the most; four students identified it as the most interesting from the set of text; seven students identified it as one of the most important for the teacher to keep and use next year (first choice for five students, and second choice for two students); and only one student identified the text as one their teacher should skip in the future.

It is telling that many of the focal students selected the text, *For Squirrels, It's Headfirst and Down*, as the one that they learned the most from, the most interesting, and one that their teacher should keep to use in the future because of how early in the unit students read this text (i.e., it was the first, of the six, interactive read-alouds in Unit 1). Thus, students' interview responses did not reveal a preference for selecting texts read more closely to the time of the interviews, which were conducted at the end of the unit. Indeed, student interviews also provided evidence that some students associated the text with the modeling task in which they engaged. For example, when explaining why the teacher should keep the text to use with her students next year, Luas explained, "because if we didn't (read it), we wouldn't know a lot about it…We wouldn't know a lot about squirrels…so they (future students) might not think that squirrels can do that (go headfirst down), so on their model they wouldn't put that." Lucas' response provides evidence that he understood that the purpose for reading the text was to provide information that students could incorporate into their models.

Conclusion

The findings described in Part I of this chapter illustrate the ways in which the text, task, and enactment worked in interplay to create opportunities for and support students' learning of science content and practices, as well as students' development of foundational and disciplinary literacies. As I will argue across these findings chapters, although we cannot isolate the features of the text from its enactment, there did appear to be affordances associated with the design of the text, the pairing of the text and modeling task, and the placement of the text in the curriculum. The design of the text and the teacher's enactment supported students to activate and build upon their prior knowledge from first-hand observations, investigations, and texts conducted and read earlier in the unit. *For Squirrels, It's Headfirst and Down* was designed to provide students with new evidence of squirrel's adaptations, creating a reason for students to revise their models. Student models provide evidence of their science content learning.

Additionally, the text, as designed for use in the written curriculum, served as a scaffold for student learning about and engaging in the disciplinary practice of modeling. My findings suggest that through planning, revising, and talking about their models with one another and their teacher, students were beginning to develop an emergent understanding of how to use models to represent a system under investigation, to explain phenomena, and to communicate ideas to others. At the same time, it was clear that learning and engaging in this practice was challenging for students and their teacher, based on evidence of the significant scaffolding the teacher provided before many students took up, for example, the use of labels to clearly communicate ideas, and including evidence from the text to enhance their model's ability to explain how squirrels survive in a particular environment.

Finally, the design of the text and task, in hand with the teacher's enactment created opportunities to support students' development of foundational literacy skills, such as comprehension of informational text. For instance, the teacher used the context of the interactive read aloud to engage students in using a number of reading comprehension strategies, such as making predictions and visualizing information in the text. Further, to both support and check for student comprehension of the ideas in the text, the teacher paused on many occasions during reading to pose and engage students in discussing literal and inferential comprehension questions about written text and images. Finally, after reading, the teacher engaged students in summarizing the key ideas of the text, on both days of instruction, and scaffolded students' connection of relevant information in the text to the modeling task. To better support teachers to engage students in text-based discussions that support sense-making, and to ask questions during reading that prompt high-level thinking, we are designing interactive reading guides to support teachers to engage in the complex work of using text to support students' science and literacy learning in the context of PBL.

PART II: Organism Structure-Function Texts

In this section, I focus on the design and use of a set of researcher-designed informational texts, which we referred to as Structure-Function Cards. Similar to the text, *For Squirrels, It's Headfirst and Down*, this text set focuses on core ideas related to adaptations that enable organisms to survive in particular environments, as well as the needs of organisms (e.g., food, water, shelter) and characteristics of their habitats. First, I describe the design features of the texts and task, and then describe the enactment. To address my research questions, I (a) describe the ways in which the design of the enactment of the text set and task supported students' science and literacy learning: and (b) identify modifications to the design of the text and task that might enhance students' science and literacy learning, in the context of project-based science instruction.

Design of the Texts: Organism Structure-Function Texts

The organism structure-function texts (see an example in Appendix B) were designed to: (a) illustrate core ideas related to adaptations that enable organisms to survive in a particular environment, as well as the needs of organisms and characteristics of their habitats; (b) provide information that connected to and built upon students' first-hand observations within and beyond the classroom, and their shared knowledge; and (c) motivate and provide information to support students' engagement in the practice of scientific modeling – to create an "interactions model" that explained how squirrels interact with other organisms in a particular environment – based on new learning.

Each of twelve texts in the set of organism structure-function texts, focused on one plant or animal that shares its habitat with Eastern Grey Squirrels. The organisms included plants (e.g., red oak tree), animals (e.g., coyote), and bacteria. Each text was structured similarly to describe the habitats of each organism (e.g., Where do ants live?), predator-prey relationships (e.g., What do ants eat? What eats ants?), and unique structures that enable the organism to survive in a particular habitat (e.g., How do ants survive in their environments?). Each of the three to four structure-function relationships identified for each of the organisms, was paired with a photograph that illustrated the structure (see Appendix B for one example).

Overview of Enactment

Prior to selecting and reading the organism structure-function texts, the teacher engaged students in reviewing a list of other organisms that live in a squirrel's habitat, generated in an earlier lesson. The teacher then introduced the texts and task and allowed pairs of students to choose and read about an organism in the squirrel's habitat that they wanted to learn more about, which spanned two days of instruction. At the end of the second day, two groups shared their learning about their organism and demonstrated how they used the text to identify information.

On days three and four of enactment, the teacher introduced the "interactions model," for which students used their learning from reading about their chosen organism to explain how each of the organisms researched interact with squirrels and one another in a particular habitat. With their partners, students prepared a small card for the interactions model, on which they drew their organism and labeled one or more of the structures that it uses to survive in its habitat. The teacher and students then worked together to illustrate how the squirrel and other organisms and interacted with one another. The lesson concluded with the teacher projecting a Google Maps satellite view of the school and inviting students to make claims about where on the map they would most likely observe squirrels and the other organisms that share their habitat. Table 4.2 provides additional details about the four days of enactment.

Table 4.2

Organism Structure-Function Text Set and Modeling Enactment Timeline

Lesson	Day	Lesson Activities
Lesson 3.2 What other organisms live in the squirrel's environment?	Day 1 ~60 mins.	• Teacher and students revisit student-generated list (e.g., based on first-hand observations and prior knowledge) of organisms that live in a squirrel's environment. • Teacher-led discussion about whether squirrels need other organisms to survive. • With a partner, students choose a structure-function text about an organism they want to learn more about. Students partner-read and answer questions about the characteristics of the organism, its needs, and habitat. • Teacher circulates and confers with groups of students about their organism.
	Day 2 45 mins.	• With their partners, students continue to read and answer questions about the characteristics of their chosen organism, its needs, and habitat. • Teacher circulates and confers with groups of students about their organism. • Two groups share their learning about their organism and demonstrate how and where they found information in the text.
Lesson 3.3 How do other organisms in the squirrel's environment help it survive?	Day 3 ~45 mins.	• Teacher introduces "interactions model" task – develop a model to explain how students' chosen organisms interact with squirrels and other organisms in a particular habitat. • With their partners, students draw their organisms, label one or more of its unique structures, and describe how the organism interacts (or does not interact) with the squirrel. • Teacher circulates and confers with groups of students about their organism. • Teacher and students begin to co-construct interactions model, placing students' drawings of their organisms on the chart paper and discussing interactions among organisms.
	Day 4 45 mins.	• Teacher and students co-construct interactions model, placing students' drawings of their organisms on the chart paper and determining how to represent interactions among organisms in the "interactions model." • **Teacher and researcher extension:** Using Google Maps, students analyze a satellite view map of their school campus and use information on their interactions model to determine where and why they would be most likely to find squirrels living near their school.

Testing Conjectures

In analyzing and reporting data specific to the design and enactment for the *Organism Structure-Function text set* and modeling task, I foreground the following features of the designed MLs learning environment (i.e., *embodiment*): (a) the designed tools and materials, including teacher supports (e.g., lesson plans), student notebooks, and multimodal literacy resources (i.e., researcher-designed texts), and (b) the task structure. The mediating processes outlined in my conjecture map served as analytic lenses, guiding my analyses of enactment data, artifacts, and interviews. For instance, to understand whether and how mediating processes produced desired outcomes within the lessons, I drew on transcript, student notebook entries, and class-generated artifact data (e.g., organism student sheet, organism interactions model) in order to closely analyze the ways in which the mediating processes emerged and unfolded in the classroom.

The close analysis of transcribed video of lesson enactment allowed me to analyze the ways in which the designed tools and materials (e.g., teacher supports, literacy resources) and task structure produced observable interactions: (a) using tools of reading, writing, viewing and discussing for meaningful purposes, (b) using scientific ideas and practices, (c) building on prior knowledge and funds of knowledge, and (d) the teacher's instructional moves. Analyzing observable interactions revealed within transcript data in combination with groups' organism student sheets and the class-generated model, as well as interview data, allowed me to examine whether and how the mediating processes led to the desired outcomes, including: (a) making sense of and synthesizing multimodal texts, (b) using science ideas and practices to make sense of and explain phenomena, and (c) developing increasingly sophisticated written and visual artifacts. I present my findings in the following section.

Findings

In this section, I present findings from my analyses of enactment data (lesson plans, field notes, transcribed video recordings, and student artifacts) and interview data with focal students and their teacher to respond to my research questions: (1) How did the design and enactment of the *organism structure-function text set* and task support third-graders' science and literacy learning? (2) How might modifications to the design of the text and task better support third-graders' science and literacy learning, in the context of project-based science instruction?

Findings from enactment. I found that the design of the texts and tasks, and the teacher's enactment of the organism structure-function texts synergistically supported third-graders' science and literacy learning. I also identified missed opportunities, both within the design of the curriculum resources and the enactment of the lessons, for further supporting the science and literacy learning of all students.

Before reading: Setting the purpose and preparing to read. Analyses of the written curriculum and transcripts of classroom enactment revealed that the teacher leveraged the texts and task to support students' science and literacy learning prior to reading by (a) supporting students to activate prior knowledge, (b) clarifying key vocabulary, and (c) setting a clear purpose for reading.

Activating prior knowledge and clarifying science vocabulary. To prepare students to select and read one of the organism structure-function texts in pairs, the teacher began the lesson by asking students to revisit a list of organisms that live in a squirrel's environment, which the class generated during the previous day of instruction (e.g., "So, yesterday you guys brought up some other organisms that were in a squirrel's environment. Do you remember what some of those organisms were?"). Doing so revealed that all students in the class had not yet developed a shared understanding of the meaning of the term, *organism*, which is an example of a discipline-specific word in science. Specialized disciplinary vocabulary is one feature of academic language that distinguishes it from everyday language and can pose challenges for students' comprehension (Snow & Uccelli, 2009). This led to a series of exchanges in which the teacher pressed for students to share and clarify their thinking about what the class could and could not classified as an organism, as they shared their prior knowledge:

Teacher: Do you remember what…organisms were?

Student: Bacteria.

Teacher: Well, bacteria is an example of an organism.

Keyanta: A living thing.

Teacher: Usually, it's a living thing.

In this example, the teacher asked students if they recalled what organisms were, as they had described them in previous lessons. One student proposed, "bacteria," possibly because the focus of a recent lesson was on bacteria. The teacher provided feedback that, while "bacteria is an example of an organism," it is not a full definition of an organism. Keyanta then proposed that an organism is a "living thing."

A few exchanges later, Nick proposed an example of an organism, which provided another opportunity for the teacher to further press for students' understanding of the term:

Nick: A hole in a tree.

Teacher: So, the hole in the tree, is that an organism or is that part of an organism?

Nick: Part of an organism.

Teacher: It would be part of the organism. Which organism would it be part of?

Nick: The tree.

In this exchange, Nick identified "a hole in a tree" as an example of an organism that lives in a squirrel's environment. The teacher followed by pressing Nick to identify whether the hole is "an organism or…part of an organism." Nick concluded that the hole was "part of an organism," and "the tree" was the organism. This exchange further refined the definition of an organism as a living thing by differentiating between the organism itself (i.e., the tree) and a feature of the organism (i.e., a hole in the tree).

In a final example, Jeremiah later suggested “a chair” as an example of an organism in a squirrel’s environment. The teacher followed up on Jeremiah’s suggestion by pointing to the list of organisms recreated so far by other students in the class.

Jeremiah: A chair.

Teacher: Okay, so do you think, look at these: molecules, bacteria, tree, foxes, woodpeckers, grass, hedgehog. Do you think a chair would fit in with those organisms? If we said that an organism is a living thing, would a chair fit in with that Jeremiah?

Jeremiah: A flower.

In this example, after the teacher reviewed the current list of organisms written on the board, she asked Jeremiah if he thought a chair would “fit in with those organisms,” and revisited Keyanta’s suggestion from an earlier exchange that and organism is a “living thing.” Although Jeremiah did not provide his thinking about why a chair would not fit into this list and the teacher did not probe his thinking in this regard, Jeremiah did respond by providing an example of a plant, “a flower.”

After activating prior knowledge about organisms that live in a squirrel’s environment, the teacher asked students to think and talk with one another about their prior knowledge related to squirrels’ needs for survival, connecting these needs to the list of organisms they generated (e.g., We just listed some organisms. Do you think squirrels need these organisms…in order to survive?). As students discussed this question with the students seated near them, the teacher paused to listen-in on some of their conversations and then invited students to share their ideas with the class.

Teacher: Did your group kind of collectively decide that, yes, they do need other organisms?

Julia: That squirrels needed squirrel friends.

Teacher: Okay, that squirrels needed other squirrels. They needed friends to survive… Raven?

Raven: I think that squirrels needed grass so they could dig a hole to hide from predators.

Teacher: Okay, so you're saying to hide…Makayla, go ahead.

Makayla: I think squirrels need other organisms. They need a tree because so they can get their acorns and so they can storage their food in there.

This brief excerpt provides a few exchanges from the beginning of the discussion in which students shared their thinking about whether squirrels needed other organisms to survive. These exchanges illustrate that students were beginning to think about interactions among organisms (e.g., other squirrels, grass, trees) in a particular habitat, and ways in which these interactions enable squirrels to meet their needs, such as shelter "to hide from predators" and trees as a source of food. This discussion served to prime students' thinking and activate their prior knowledge about other organisms that live in a squirrel's environment and the ways in which organisms interact to meet their basic needs for survival, prior to selecting and learning more about a particular organism.

Setting a clear purpose for reading. A final way in which the teacher and the written curriculum supported students' science and literacy learning prior to reading was by previewing the texts and setting a clear purpose for reading. First, the teacher described the task that students would complete while reading (e.g., “You’re going to do some research, some investigating about other animals in a squirrel’s environment. You are going to be able to choose one of the organisms from a list that’s already been provided.”). Based on observations of the challenges students encountered when asked to identify text evidence from *For Squirrels, It’s Headfirst and Down,* the teacher and researchers decided to further scaffold students’ reading of the organism structure-function texts by providing a set of guiding questions to which students responded as they read about their selected organism. Thus, part of setting a clear purpose for reading, in this case, involved previewing and clarifying each of the questions that students would respond to as they read (e.g., “The directions say read all about your organism first and then use the text to answer the questions with your partner. What does that mean, use the text?).

The questions included on the student sheet were designed to scaffold students’ reading and interpretation of the organism structure-function texts. Specifically, the guiding questions were designed to support students to identify key ideas in the text in order to use those ideas to inform the co-construction of the “interactions model.” As the teacher previewed and introduced each question, she also supported students to connect to prior knowledge and experiences in the unit in order to scaffold students’ understanding of the task (e.g., “The second thing says list the structures. Now remember, remind me what kind of a structure does a squirrel have to help it, let’s say eat acorns or go down a tree headfirst?”). For example, when introducing the question about identifying organisms’ structures, the teacher engaged the class in revisiting the squirrels’ structures that they read about in the text, *For Squirrels, It’s Headfirst and Down*, and from their first-hand investigations.

During reading: Supporting students to read and interpret information. Analyses of the written curriculum (e.g., texts, lesson plans, and other student resources) and transcripts of classroom enactment revealed that the teacher leveraged the text and task in support of students' science and literacy learning by supporting students to read and interpret the information in the texts. Students' partner reading and interpretation of their chosen organism structure-function text was scaffolded by the guiding questions themselves and the teacher's use of these questions as she talked with individual and small groups of students about their reading and learning from the texts.

Using the guiding questions to scaffold reading and interpretation of text. The majority of the second day of enactment was dedicated to students' reading their selected organism structure function text and working with their partner or group members to respond to the guiding questions. The guiding questions were as follows: (1) What is your organism? (2) List the structures you read about. (3) Choose one of the structures you listed. How does this structure help the organism meet a basic need? (4) Does your organism live in the same environment as squirrels? How do you know? (5) You have learned that food is important for organisms to survive. What foods does your organism need to survive? (6) You have also learned that organisms must escape predators to survive. What predators eat your organism?

The guiding questions were designed to support students to identify information in their text related to the ways in which their organism interacts with the squirrel and other organisms in a particular environment, in order to co-construct an environment interactions model with their class on days three and four of enactment (e.g., predator/prey relationships, habitat, structure-function relationships). On day two, as the teacher circulated and conferred with groups during reading, she leveraged the guiding questions to check for student understanding.

Teacher: What are you doing?

Brianna: We're doing garden spider.

Teacher: Okay. Oh, you're doing garden spider? I haven't seen anybody do that one yet. Awesome! So, what are the structures you read about?

Kaylee: Fangs.

Brianna: We read about their fangs.

Teacher: Fangs.

Brianna: We read about their hairs.

Kaylee: Hairs.

Teacher: Hairs.

Brianna: We read about the claws on their feet and the spin…

Teacher: Spinnerets.

Brianna: Oh yeah, that's what it is.

Teacher: So, make sure you understand what each of those are.

Brianna: Okay, I can tell you what they are.

Teacher: Well, here's what you're going to do, remember? You're going to choose *one* of the structures you listed.

In this example, the teacher paused to talk with Brianna and Kaylee's group as they read about Garden Spiders. The teacher began by asking the students which organism they selected and the structures they read about. Brianna and Kaylee identified the structures they read about in the text (i.e., fangs, hairs, and spinnerets). Then, before moving to another group, the teacher prompted the students to make sure they understood what each of those structure was, and to select and describe one of those structures on the guiding question sheet. Throughout day two of enactment, the teacher circulated and conferred with small groups and individual students about their reading and interpretation of the text, using the guiding questions to support students to identify and describe key ideas.

Analysis of students' responses to the guiding questions provided additional evidence that the questions scaffolded students' reading and interpretation of the organism texts to inform the co-construction of their interactions model. While each focal student did not complete all of the guiding questions (ten of the sixteen focal students completed all six questions), all focal students identified their organism, listed structures from the text, and described how one of those structures enables the organism to survive in its environment. The NRC Framework explains that, "the quality of a student-developed model will be highly dependent on prior knowledge and skill and also on the student's understanding of the system being modeled" (NRC Framework, 2013, p. 59). In other words, the quality of the class-developed environment interactions model depended on students' prior knowledge and understanding of the environment system, including the organisms that are a part of that system. Thus, I argue that, in hand with students' first-hand observations and investigations of organisms and their interactions in the environment (e.g., field work around the school and observations at home), the information in the organism structure-function texts – designed to build on students' prior knowledge and experiences in the unit – and the scaffolding provided by the guiding questions supported students to build the prior knowledge necessary to co-construct the interactions model.

After reading: Using text information to inform construction of interactions model. Analyses of the written curriculum (e.g., texts, lesson plans, and other student resources) and transcripts of classroom enactment revealed that the teacher used the lesson plans, text, and task to scaffold students' use of text information to inform the co-construction of the interactions model by supporting students to (a) share their learning from text with one another to develop shared-knowledge (Days 2 and 3), (b) use their shared-knowledge to co-construct the interactions model (Day 4), and (c) apply the model to explain organisms' interactions in a local context (Day 4).

Sharing learning from text to build shared-knowledge. After reading the text, the teacher leveraged multiple opportunities for students to share what they learned about their selected organism with the rest of the class. This was important because, in order for students to co-construct a model to explain how organisms in the environment interact with the Eastern Grey Squirrel and with one another, the students needed to build shared knowledge about the organisms and their interactions in the environment.

On day two of enactment, after all groups read about their organisms and responded to the guiding questions, the teacher invited students up to the front carpet to debrief their findings. To conclude this day of enactment, two groups had the opportunity to (a) present what they learned about their selected organism by sharing their responses to the guiding questions and also to (b) show the class both how and where they identified this information in the text. For example, when Makayla and Sam shared their learning about the Earthworm, the teacher pulled up the Earthworm text on the SMART board and asked the students to show the class where they found information to respond to the guiding questions.

Teacher: So, tell us what organism you did some research on?

Makayla: …Our organism was earthworm.

Teacher: So maybe while she's (Makayla) talking, you (Sam) could go to the earthworm [on the SMART board]. You could tap the earthworm (link to the text), alright? So, what was the first thing that you had to find…?

Makayla: What is your organism?

Teacher: Alright, so you did that. And then?

Makayla: List the structures you read about.

Teacher: Okay, so…where did you find your structures? [Makayla scrolls down the screen to the section of the text that described the earthworm's structures] …Sam, do you want to tell us, since she just scrolled it? …What was the first structure that you found that helped the earthworm survive in its environment?

Sam: Mucus.

This excerpt illustrates how the teacher guided students to share their learning from text and how they used the information in the text to respond to the guiding questions. Here, the teacher supported students to share what they learned from researching their organism by using the guiding questions as talking points. Additionally, she projected the organism structure-function text the presenters read and asked them to identify how and where they found information in the text that helped them respond to each of the guiding questions. As this exchange continued, Makayla and Sam shared additional findings with the class, each time prompted by the teacher to show the class how and where they identified this information in the reading. Thus, in addition to supporting students to share their findings with the class to build shared knowledge among students, the teacher also supported students to navigate and identify information in the text that supported their responses to the guiding questions.

On day three of enactment, the other groups had the opportunity to share their learning from their organism text, although more briefly than on the previous day. Recall that, on this day of instruction, the teacher introduced the modeling task, and students used what they learned about their organism to create a small drawing of their organism, on which they labeled one or more of the organism's structures and described how it interacts with the squirrel. After completing this step, each group had the opportunity to share and post their organism card on the chart paper where the class would co-construct the interactions model (see Figure 4.5 below).

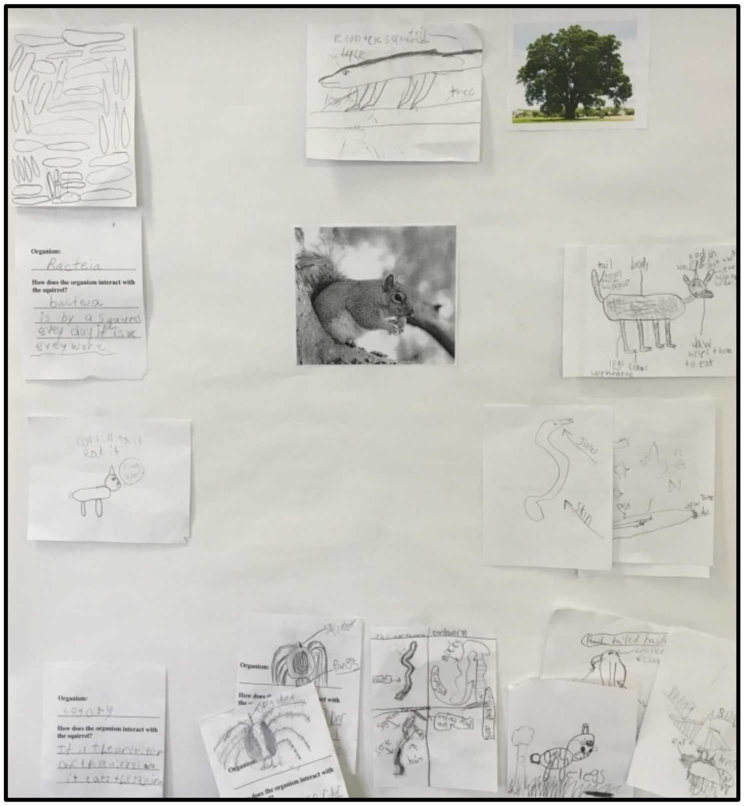

Figure 4.5. Groups' organism cards taped around the squirrel, prior to developing a model to represent their interactions.

After students created their organism cards, for each of the twelve organisms, the teacher invited students to tape their cards on the chart paper (Figure 4.5, above), and to share their learning about the organisms' structures and how they interact with the squirrel in the environment. The following excerpt provides an illustrative example of these exchanges, in which students who read about the coyote shared and discussed with the class the coyote's structures and how it interacts with the squirrel in the environment.

Teacher: What was one structure that you labeled on your coyote?

Cameron: …the rod in their eyes because it helps them see in the dark and get their prey.

Teacher: Okay, can somebody repeat what Cameron said? …Nick, what did he say?

Nick: He labeled the eyes because it helps it see in the dark.

Teacher: Okay, and there was something even more specific that he motioned other than just the eyes. Makayla, what did you hear him say?

Makayla: The rods in the eyes.

Teacher: The rods that are in their eyes. Okay, so they have special rods in their eyes that allow them, you said, to see better in the dark…How do they interact in a squirrel's environment?

Owen: It is the predator of a squirrel…so coyotes *should* live in the squirrels' environment…

Teacher: Why *should* they live in the squirrel's environment?

Owen: Because the coyote eats the squirrel.

By the third day of enactment, based on students' readings of multiple texts and whole-class conversations about each of the organisms, transcripts revealed that students were developing shared knowledge of the different organisms, structures that enable them to survive in their environment, and ways in which they interact with squirrels and one another.

Using shared knowledge to co-construct the interactions model. After sharing their learning about the organisms to build shared-knowledge across members of the class, the teacher supported students to use what they knew about the organisms, their structures, and interactions in order to co-construct the interactions model to explain how squirrels interact with other organisms in a particular environment. To launch Day 4 of enactment, the teacher introduced the modeling task, previewed on days prior, and invited students to suggest ways in which they could represent interactions among the organisms from the readings. Recall that on Day 3 of enactment, students drew their organisms and labeled their structures on small cards, which they placed on a sheet of chart paper around a photograph of a squirrel placed in the center (see Figure 4.5).

Teacher: Based on the structures and the functions of the structures, we're going to look back at this model and we're going to talk about how these things interact with a squirrel in its environment…Tell me some way in which these things interact with each other or the squirrel in this environment. Ellie, what's one thing that happens?

Ellie: Some of them are predators.

Teacher: Don't say some. Give me something specific. Can you zero in on one organism? (The teacher clarifies the directions.)

Ellie: The red-tailed hawk is a predator of say the squirrel or the cotton-tail rabbit.

Teacher: So, what could we do to show that the red-tailed hawk is a predator to both the squirrel and the cottontail rabbit? What could we do?

Kaylee: We would look on the Chromebook.

Teacher: No, what could we do to show on our model, right here, that the red-tailed hawk is a predator to the squirrel and a predator to the cotton-tail rabbit? Does anyone else have an idea of something we could do? (Other students share ideas, such as “act it out” or “write it.” The teacher continues to press for additional suggestions.)

In this exchange, the teacher introduced the modeling task and prompted students to share examples of the ways in which the organisms on the chart paper interact with “each other or the squirrel.” Ellie first claimed that some of the organisms are predators. In response, the teacher pressed Ellie to provide a specific example to illustrate her claim. After providing an example (i.e., “the red-tailed hawk is a predator of…the squirrel or the cotton-tail rabbit”), the teacher challenged students to figure out how they could represent predator-prey relationships in this model.

As this exchange continued, students initially proposed that they could “look on the Chromebook” to show relationships, “act it out,” or “write it.” In response, the teacher pressed students to think of ways they could represent these relationships directly on the chart paper to clearly communicate the relationships with others. The design of this modeling task and the way in which the cards were arranged on the chart paper called for students to create a more abstract representation than the squirrel environment models described in Part I of this chapter, in which students drew and labeled concrete pictures. As the teacher pressed for more ideas, one student proposed that they could draw and label lines between organisms and label these lines to communicate the nature of the organisms’ relationship (e.g., predator/prey, shelter, etc.).

Owen: You could like draw like a green line from the red-tailed hawk to the squirrel and the rabbit.

Teacher: Okay, and to the rabbit?

Owen: Yeah, and then, and there’s red going…

Teacher: Okay, hold on hold on. What does that mean though? If I just drew the arrows, if Mr. Norton (the school principal) walked in, would he know what these arrows are for?

Students: No.

Owen: You could put like "predator" on the line. (The teacher writes this on the chart paper).

Teacher: What else could we do, Makayla?

Makayla: On your picture, you can draw a tree with maybe a squirrel on it, with the hawk going after it.

Teacher: Okay, so we have a tree up here. We have got the squirrel. What could we do to show that relationship or show the interaction between the squirrel and the tree? What could we do to show that relationship, or how those two interact? The red-tailed hawk and the squirrel or the red-tailed hawk and the cottontail rabbit, the way they interact is the red-tailed hawk is a predator. And we showed that with a line and we wrote the word "predator" on it. So, what could we do to show that relationship, Makayla?

Makayla: You could draw a line from the tree to the squirrel.

Teacher: Okay, if we drew a line from the tree to the squirrel, does the tree do something to the squirrel?

Kaylee: No, the squirrel lives in the tree.

Student: No, that's it's home.

Student: A nest.

Teacher: Okay, so maybe we want to go from the squirrel to the tree.

Student: And then write home.

Teacher: Okay, home. I'll do "home/nest."

Christian: Shelter, you could put shelter.

Teacher: Okay, or shelter, certainly… Is there any other kind of interaction between the squirrel and the tree? …Lucas?

Lucas: The squirrel, it gets food from the tree.

Teacher: Okay, so it gets food from the tree as well… (The teacher continues to draw and write on the chart paper.)

Lucas: And it gets predators from the tree because predators live in the tree.

This excerpt illustrates the ways in which the teacher supported students to co-construct a way to represent relationships among organisms in the interactions model. At the beginning of this exchange, Owen suggested that they could draw lines between organisms that interact. The teacher took up this idea, but she pressed for Owen to elaborate on how they could clarify the meaning of the lines. At this point, Owen suggested adding a label to the lines (e.g., predator) to describe the relationship. Recall that the use of labeling in models was emphasized when students developed their squirrel survival models.

While the teacher took up the idea of drawing and labeling lines to show the interactions among organisms, this was not yet the case for all students in the class. As this exchange continued, Makayla proposed an alternative approach, similar to the squirrel survival model (i.e., "you can draw a tree with maybe a squirrel on it, with the hawk going after it"). In response, the teacher reviewed Owen's proposal, which was already represented on the chart paper, and asked Makayla how they could use this approach to identify additional relationships among the organisms posted. As this exchange continued, the teacher invited students to identify additional relationships among organisms, based on the information from the texts, in a similar fashion (see Figure 4.6).

A final excerpt illustrates the ways in which the teacher invited students to elaborate on relationships between specific organisms by identifying how organisms use their unique structures to, for example, capture prey or evade predators, information which was emphasized in the organism structure-function texts.

Zayn: Line with the squirrel to the red-backed salamander. The squirrel is a predator to the red-backed salamander.

Teacher: The squirrel is a predator to the red-backed salamander. Okay, so the squirrel goes after… [Teacher draws and writes on the chart paper.] Now, what's the special structure that the salamander has that allows it to get away…from the squirrel? Zayn, go ahead.

Zayn: Its tail.

Teacher: What does its tail do? …go ahead, Zayn.

Zayn: Falls off so it can run away and once it run away, far away, it grows a new one.

In this example, Zayn proposed drawing a line between the squirrel and the red-backed salamander, explaining that the squirrel is a predator to the salamander. After drawing and labeling a line between these two organisms, the teacher asked Zayn to remind the class of the "special structure that the salamander has" that enables it to evade predators. Understanding and being able to explain the organisms' unique structures and their functions, supported students' explanations of complex interactions among the organisms in a particular environment.

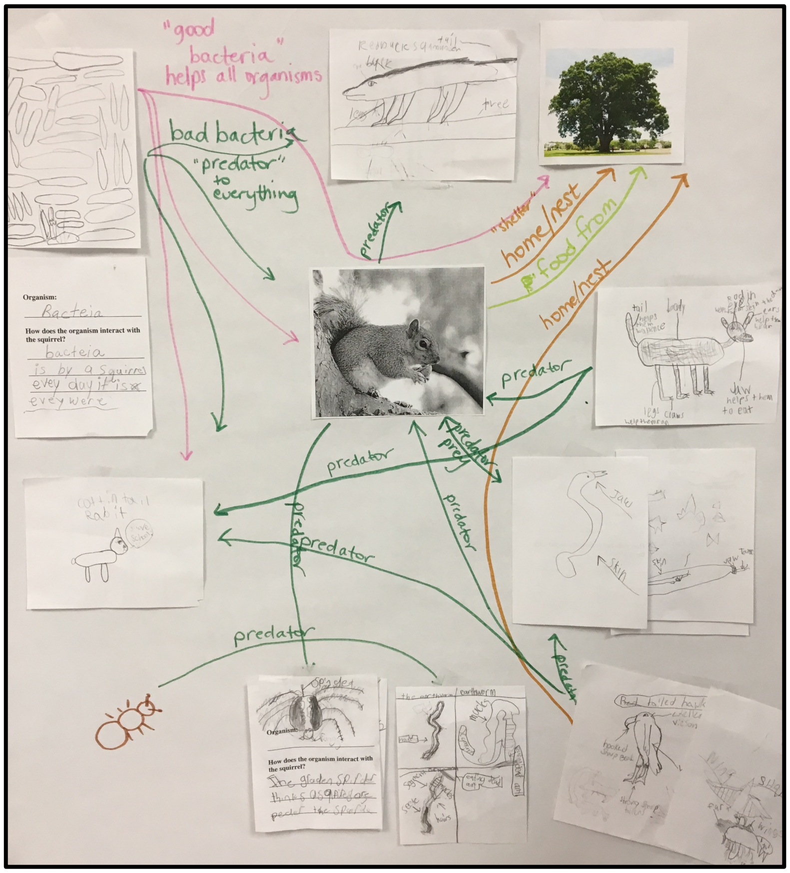

Figure 4.6. Final, co-constructed interactions model.[4]

Applying the interactions model to a local context. Finally, after using shared knowledge to construct the organism interactions model, the teacher extended the written curriculum by engaging students in analyzing a satellite view map of the area around their school and using their model to make predictions about where on the map students would most likely find squirrels and why. The classroom teacher and researcher planned this extension to the written curriculum based on the need to modify an upcoming lesson, which, as written, was more relevant to the experiences of students living and attending schools in more urban areas (i.e., areas where there are fewer trees).

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[4] The class-developed environment interactions model does not represent the energy flow model that would be used in a scientific food chain or web.

After the class co-constructed the interactions model, the teacher projected a satellite view map of the area around their school (see Figure 4.7, below). Prior to asking students to use their interactions model to apply the phenomenon under investigation to a local context, she first support students to analyze and interpret the map more generally.

Teacher: Tell me what this is a map of, Jenna.

Jenna: The school.

Teacher: How do you know, Jenna? What do you see?

Jenna: I see the bus loop?

Teacher: You see the bus loop right here?

Jenna: Uh huh.

Teacher: Okay, bus loop, right? What else do you see that tells us that's a map of our school? Julia?

Julia: I see Slate, and Birch, and Exemplar (other elementary schools in the district).

Teacher: Okay, so I'm hearing you say you see Slate, there's Birch, and there's Exemplar. Christian, what do you see?

Christian: Jefferson High School and Jefferson Middle School.

Teacher: Okay, so you see the two, high school and the middle school. What else are you seeing on there, Carter?

Carter: Jefferson Consolidated Schools.

Teacher: Alright, there up by Slate. Absolutely. Aiden?

Aiden: It says Pinnacle Methodist Church.

Teacher: Okay, yep. That's the building that's right across the street. Don't stand up and look at it. It's right across the street. We'll look later…

Student: I see a baseball diamond.

Teacher: Yep, there would be the cloverleaf fields. Right over here is pretty much where we're at, right in the corner of the building, pretty much right now. This is literally Wellington road. This is White road.

This excerpt illustrates how the teacher leveraged the instructional context to support students' graphic literacy by orienting them to the map of the area around their school. In this exchange, the teacher scaffolded students' identification of particular locations on the map prior to asking them to apply their interactions model to the local context. In interpreting the map, students were able to draw on prior knowledge of the landmarks and buildings because it represented an area with which all students were quite familiar – their school campus. In the example, the teacher asked students to identify what "this is a map of," and to explain how they knew based on the various landmarks, buildings, and road depicted. This orientation supported students to use the information on the map for the purpose of using their interactions model to make predictions about the phenomenon under study.

Once students identified locations on the map, the teacher asked them to make connections between their co-constructed interactions model and the features of the environment in the area around their school.

Teacher: Based on our interactive map [and] based on what we know about squirrels and their environment, if we were to say we're going to take a field trip on our campus because we want to try to see these squirrels active…based on what we know about squirrels, where do you think we would be able to find the most squirrels? …Think about that and be able to tell me why you think that…What are your thoughts, Raven?

Raven: You can find them in a tree.

Teacher: Okay, so we want to look for an area that has trees. What do we not see a lot of around our building?

Students: Trees.

Teacher: We don't see a lot of trees, do we? So, can you, do you see an area where there's a lot of trees, Raven? Can you come up and point that out to us? [*Raven comes up and points to a location on the map.*] Okay, so right along here.

This excerpt illustrates the way in which the teacher began to support students to connect the relationships among organisms that they identified on the interactions model to the area around their school. Because the purpose of the model was to explain how squirrels interact with other organisms, the teacher asked students to think about their interactions model and what they know about how squirrels survive in their environment, in order to predict where they think they would find the most squirrels around their school. Raven suggested that they could find squirrels "in a tree" – an organism included in the interactions model – and came up to the map to point out locations where there were few trees and locations where there were many trees (see Figure 4.7 below).

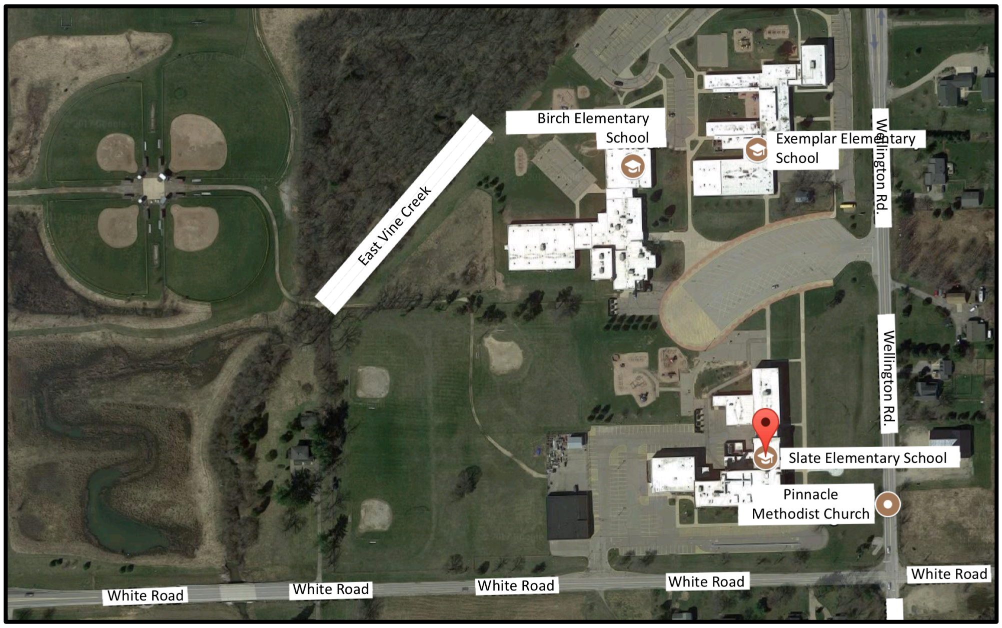


Figure 4.7. Satellite map view of the area around the school (all labels are pseudonyms).

As the discussion continued, the teacher questioned students about food sources for squirrels, beyond the acorns squirrels could find from trees, which Raven identified on the map. The following excerpt illustrates the ways in which the teacher supported students to make additional predictions, using the evidence from the interactions model and their firsthand experiences, about other organisms they might find in the area, such as frogs, salamanders, or coyotes.

Teacher: We weren't surprised that squirrels eat acorns. We kind of know that. What was it we were kind of surprised about, Ellie?

Ellie: That they ate frogs?

Teacher: I remember being pretty surprised that they ate frogs.

Kaylee: And mushrooms.

Teacher: …What else is right here by all of these trees that would be great for that squirrel's environment, that might not just give it the acorns, but maybe some frogs or some salamanders? What else is there? …What do you see there?

Student: The holes in the ground that could give it some water.

Teacher: Okay, there's something more specific about the water? Jeremiah?

Jeremiah: Earthworms…

Teacher: Okay, I'm going toward the water more. Owen?

Owen: One time I have been back there and I saw a river.

Teacher: Okay, and we would call it a creek. If you see right here it says, "East Vine Creek right there…What do you know about that area right there?

Makayla: That there could be some salamanders there.

Teacher: Okay, so this right here, that Makayla's referring to, when you guys drive maybe from Slate and you go to the high school, it's kind of like a marshy area. It's got lots of kinds of cattails and other marsh-like plants or organisms…that are growing from it. You can't always see the water there, but it is. There's water there and it would certainly be somewhat of a food source or water source for the squirrels… Based on what we know about squirrels, do you think we'd find any other kind of animals out there? You guys mentioned, based on our interactive model, the way that these things interact with one another. If there are squirrels in this area, what else might we find out in this area? And again, if you can't remember, look back to our interactive model…Cameron?

Cameron: One time when I was, me and my dad were talking with my friend's grandma and when we looked over we saw a coyote's tail running by over by the clover leaf.

Teacher: Okay…if coyotes like to eat squirrels…Cameron mentioned it, that he actually saw a coyote in that area, okay? The coyote would be there, not just for the squirrels but what else? For other food. What else might be there?

In this excerpt, the teacher prompted students to think about other organisms represented on the interactions model that they might find in the area around their school based on the organisms' interactions with squirrels. The excerpt began with the teacher asking students about other sources of food for the squirrels. Students suggested a number of ideas, such as frogs, mushrooms, and earthworms, which were followed by the teacher's suggestion of salamanders, also from the model.

To support students to think about why they might find these types of organisms in this area, the teacher posed the following question: "What else is right here by all of these trees that would be great for that squirrel's environment, that might not just give it the acorns, but maybe some frogs or some salamanders?" In response, Owen suggested that he had been in that area before and saw a river, which the teacher pointed out on the map and identified as a creek. Makayla then suggested that there could be salamanders near the creek. The text about the red-backed salamander indicated that, "You can often find them near water because they must keep their skin wet." The teacher continued to press for student ideas about other organisms that they might observe in this area based on evidence from their interactions model. In a final exchange, Cameron, drawing on both evidence from the interactions model and firsthand observations, identified the coyote as another organism that could live in the area.

Using the map as an opportunity for students to apply their interactions model to describe the phenomenon under study and to use the model to make predictions about where they might locate certain organisms based on their interactions, created opportunities beyond those suggested in the written curriculum for students to apply their learning from text, to use their model to describe and predict phenomena, and to develop skills for interpreting graphical information (e.g., analyzing and interpreting the satellite view map). As Siegel (2006) explained, when learners are supported to move across multiple modes of representation, they have opportunities to identify relationships between them, which may lead to more complex and deeper conceptual understandings. The ways in which the teacher oriented students to the digital map before asking students to synthesize their firsthand experiences, knowledge from reading (represented in the interactions model), and information in the map were also important; the teacher first provided scaffolded opportunities for students to analyze and interpret the information in the map (e.g., "Tell me what this is a map of… How do you know? …What do you see?). Interpreting the information in the map was also supported in that the map represented the area around the school, with which the students were very familiar.

Constraints of the texts and task revealed through enactment. In addition to the ways in which the text and task supported students' science and literacy learning, my analyses revealed limitations of the design and enactment of the written curriculum. One limitation of the written curriculum was the lack of science content knowledge supports for the teacher. This was particularly salient in the portion of the lesson in which the students brainstormed examples of organisms and co-constructed the meaning of the term "organism" before reading the organism texts.

There were two instances in which the enactment may have contributed to confusion among students about what does and does not qualify as an organism. For example, at one point in the exchange, the teacher modified a claim made by a student that an organism is "a living thing," by adding that "Usually, it's a living thing." Additionally, when a second student suggested "molecules" as an example of an organism, the teacher took up this example and included it in the class' list of organisms. While molecules do make up living organisms, they also make up nonliving things. Research on teachers' use of educative supports with curriculum materials suggests that teachers use subject matter supports to enhance their own learning of the concepts within a subject and to inform their teaching of both science practices and core ideas (e.g., Arias, Bismack, Davis, & Palincsar, 2016; Schneider & Krajcik, 2002). Providing this type of subject-matter information in future iterations of the written curriculum may better-support the teacher to scaffold students' understanding of science vocabulary and the concepts they represent prior to, during, and after reading.

Findings from student interviews. In this section, I describe findings from interviews conducted with focal students, which provided additional insights about students' perceptions of and learning with the Unit 1 texts. The portion of the interview specific to the organism structure-function texts, addressed here, began by presenting students with screenshots of the first page of each of the twelve texts. Focal students were asked the following questions: (1) Do you remember the text(s) you read from this set? (2) What do you remember about the text(s)?

For the organism structure-function texts, all sixteen focal students recalled which of the texts they selected and read in class. Four students recalled reading multiple texts from the set.

When asked what they remembered about the text(s), nine of the sixteen students identified and described one or more of the organisms' structures (see examples in Table 4.3, below).

Table 4.3

Organism Structure-Function Text Set Interview Excerpts

Examples from Interviews
Aiden: "That it (Eastern garter snake) has a detachable **jaw** that can pretty much open at any height and…it can eat a fish easily."
Brandon: "His (red-tailed hawk) **beak**…it's really sharp. His **claws**…they pick up the prey."
Carter: "The earthworms have **mucus** around their body to move through the soil."
Christian.: "They (Eastern garter snake) can detach their **jaw** so they can eat their prey whole."
Ellie: "They (red-tailed hawks) have very keen **eyesight**. They have a hooked sharp **beak**…they have unique strong curved **talons**."
Leon: "They (red-tailed hawk) have good **eyesight**…to find their prey."
Lucas: "It (bacteria) had a fire **wall** (cell wall) and stuff like that." Interviewer: "Okay, and what does that do?" Lucas: "It protects them."
Raven: "They (earthworms) have this **slimy stuff** (mucus) on their skin to move through the soil and so they can move really fast through the soil to get away from predators."
Zayn: "That his (red-backed salamander) **tail** can pop off…when a predator carries 'em."

It is telling that three of the six students who did not identify any of the organisms' structures, when asked what they remembered about their text, were students who chose to read about bacteria – the one type of organism from the set that is microscopic and whose structures share few similarities with the structures of the other plants and animals included in the text set (e.g., flagella, endospores, and cell wall). Additionally, the bacteria structures described are impossible to observe in a first-hand way, without a powerful microscope. While the majority of students were familiar with the other organisms in the set, this unit of instruction was the first time many students were introduced to bacteria as an organism.

Conclusion

The findings described in Part II of this chapter illustrate the ways in which the text, task, and enactment worked in interplay to create opportunities for and to support students' science and literacy learning. There appeared to be affordances associated with the design of the texts, the pairing of the texts and the modeling task, and the placement of the texts and task in the curriculum. Similar to Part I, the design of the texts and the teacher's enactment supported students to activate and build upon their prior knowledge from first-hand observations, investigations, and texts read earlier in the unit. The organism structure-function texts were designed to build upon students prior learning about structure-function relationships specific to squirrels (as featured in *For Squirrels, It's Headfirst and* Down), to provide students with new information about how organisms' unique structures support survival and interact with one another, and to create a reason for students to develop a new, more abstract, model to explain how squirrels interact with other organisms in their environment. The co-constructed interactions model, informed by the information students gathered and synthesized from the texts, provides evidence of their science content learning.

Similar to the role of the text in Part I, the organism texts served as additional scaffolds, or catalysts, for students' engagement in the scientific practice of modeling. My findings suggest that through co-constructing the interactions model, students continued to develop their understandings of how to use models to represent a system under investigation, to explain phenomena, to communicate ideas to others, and to make predictions.

Finally, the design of the text and task, in hand with the teacher's enactment created opportunities to support students' development of foundational literacy skills, such as comprehension of informational text. For instance, the teacher used the guiding questions to support students to locate and discuss key ideas in the text. Finally, after reading, the teacher engaged students in communicating key ideas in the texts by creating organism cards that groups placed on the interactions model, prior to identifying the relationships among these organisms. This scaffolded students' connection of relevant information in the text to the interactions modeling task. To support teachers' subject matter knowledge in order to better facilitate students' science learning, vocabulary development, and sense-making with text, we are designing educative curricula in the form of content knowledge supports for teachers.

CHAPTER V: UNIT TWO

How can we design fun moving toys that any kid can build?

The instructional context for this chapter is the second *Using Multiple Literacies in Project-based Learning* (*MLs*) unit of instruction focused on disciplinary core ideas related to force, motion, and engineering design. The unit is framed by the following driving question: *How can we design fun moving toys that any kid can build?* In the unit, students work to design moving toys for younger children at their school and explain how different forces affect their toys' motion. Throughout the unit, students have opportunities to read a variety of text types, such as procedural, biographical, and informational text.

In the first part of this chapter, I focus on the design and enactment of a text set from this unit that included a researcher-designed biographical text about Lonnie Johnson and his use of engineering design ideas and practices to design the Super Soaker. In the focal classroom, this researcher-designed text was paired with a video and trade book that engaged students in further exploration of Lonnie Johnson's use of engineering design ideas and practices. The learning goal for the lesson was the following: *Students will obtain information from text to define solutions to design problems by applying scientific ideas to developing new toys.* In the second part of this chapter, I focus on the design and enactment of another text from this unit called *The Balloon Rocket Story*, which is accompanied by an investigation of the role of friction in motion. The learning goal for the lesson was the following: *Students will collaboratively plan and conduct an investigation using fair tests to determine how using different strings (different amounts of friction) with the balloon rocket system impact the motion of the balloon rocket.*

The Unit of Instruction

In this section, I describe the progression of the PBL unit leading up to the Lonnie Johnson text set and *The Balloon Rocket Story* to situate these text-reading events within the larger unit of instruction. Following the introduction of the unit driving question (*How can we design fun moving toys any kid can build?*), students began the unit by making observations of commercially produced moving toys, such as air rockets. After observing moving toys and investigating causes of motion (e.g., often a push or a pull), with a partner, students selected a toy from three options (cart, skimmer, or water bottle rocket) and built simple prototypes of the toys using written and video instructions. Once students built the toy prototypes, partners tested their toys' motion and record observations of how their toys started to move. These observations culminated in students' development of scientific models that explained the forces that caused their toys to start moving.

In the set of lessons that followed, students brainstormed reasons why children might want or need to build their own toys and discussed ways the class could figure out the types and features of moving toys other children would enjoy. With their partners, and then as a class, students generated interview questions to ask younger children in order to gather feedback for improving their initial toy prototypes. Next, students conducted interviews with kindergarteners, debriefed the interview feedback as a class, and began to plan for making one of the suggested changes to improve their toy designs.

Next, students were introduced to the engineering design process by exploring another toy – the Super Soaker – and reading a researcher-written biographical text about its designer, Lonnie Johnson. During this interactive read-aloud, students were supported to make connections between the engineering design practices that Lonnie Johnson used to develop the

Super Soaker and the practices in which the students engaged as they worked to build and improve their own toy prototypes. The researcher-written text was paired with a short video and a trade book, *Woosh! Lonnie Johnson's Super Soaking Stream of Inventions*, both of which further illustrated the design work of Lonnie Johnson and the engineering practices he used as a toy designer. This text set was designed to inform and motivate students to plan and make improvements to their own toy designs.

Finally, students were introduced to another toy, the balloon rocket. Investigating the balloon rocket toy in the classroom and reading and discussing *The Balloon Rocket Story* served as contexts for thinking about: (a) how the parts of a system work together, (b) designing and conducting fair tests, (c) making scientific observations, and (d) the role of friction in motion.

PART I: Lonnie Johnson and the Super Soaker Text Set

In this section, I focus on the design and use of a researcher-designed biographical text, *From Water Squirter to Super Soaker: How Lonnie George Johnson Changed Water Games* (Appendix C), and teaching guide (Appendix D). This text focuses on practices and core ideas related to engineering design and was paired with a video and trade book of the same topic. First, I describe the texts and teaching guide included in the Lonnie Johnson text set, provide an overview of the design features of the texts and tasks, and describe the enactment. To address my research questions, I (a) describe the ways in which the design and enactment of the Lonnie Johnson text set, teacher resources, and tasks supported students' science and literacy learning; and (b) identify modifications to the design of the text and tasks that might enhance students' science and literacy learning, in the context of project-based science instruction.

The Texts: Lonnie Johnson Text Set

The Lonnie Johnson text set included a researcher-designed biographical text (*From Water Squirter to Super Soaker*), video, and trade book (*Whoosh! Lonnie Johnson's Super Soaking Stream of Inventions* by Chris Barton). The researcher-designed text was designed to: (a) illustrate core ideas and practices related to engineering design, (b) provide information that connected to and built upon students' first-hand observations and shared knowledge, (c) provide a context for students to compare their own design work to the work of practicing engineers, and (d) motivate students' use of the engineering design practices to improve their own toy designs.

From Water Squirter to Super Soaker begins by describing how the Super Soaker addressed the problem of early toy water squirters that were fun to play with, but didn't get anyone very wet, and explains that the story of the Super Soaker began in Alabama in the home of Lonnie George Johnson. The text continues by describing Lonnie's childhood, as well as his interest in figuring out how things worked and designing at an early age. The text transitions from describing Lonnie's childhood interests and inventions to describing how he pursued a career in engineering by studying at Tuskegee University and eventually by working as an engineer for NASA. Finally, the text describes the series of events that led to Lonnie's design and production of the Super Soaker.

The interactive reading guide that accompanied the text was designed to support the teacher's enactment and to engage students in reading, interpreting, and discussing the ideas in *From Water Squirter to Super Soaker*. Specifically, the viewing guide was designed to include a variety of (a) discussion questions and prompts; (b) opportunities to engage students in first-hand observations and demonstrations (e.g., observing compressed air in a balloon, analyzing the parts of the Super Soaker system and how they work together); and (c) supplemental information for the teacher to share and discuss with students about Lonnie Johnson, his work as an engineer, and engineering design practices.

The paired video both repeated information from the text and provided new information about Lonnie Johnson's work as an engineer. Finally, the trade book complemented the researcher-designed text and the video by repeating information from the previous sources and by providing additional details about Lonnie Johnson's life and motivation to create inventions and pursue a career in engineering.

Overview of Enactment

To begin the lesson that featured the Lonnie Johnson text set, the teacher invited students to gather on the carpet in the front of the classroom. Here, the teacher presented three different water squirters, including the Super Soaker, and asked students to observe and describe what they noticed about each toy. As students shared their observations about the parts of each toy system, the teacher recorded students' noticings and observations on chart paper.

After passing each water squirter around the circle and recording students' observations, the teacher asked students to make predictions about which water squirter they thought would shoot water the farthest, pressing for students with differing predictions to explain their thinking about why they thought one water squirter might shoot farther than the others. Before going outside to test which water squirter would shoot the farthest, the teacher led students in a brief discussion about how they could plan and conduct an investigation to answer this question.

During the next day of instruction, the teacher introduced the researcher-designed text, *From Water Squirter to Super Soaker*, and made connections to students' experiences observing the parts of different water squirter systems and testing which shot water the farthest distance. Prior to reading, the teacher also prompted students to think about the Driving Question for the unit (*How can we build fun, moving toys that other kids can build?*). After priming students' thinking about their experiences and the Driving Question, the teacher engaged students in an interactive read-aloud of the text, pausing frequently to ask questions and discuss the information in the text. After reading and discussing, the teacher invited students to gather on the carpet in the front of the classroom to view and discuss the paired video that described Lonnie's engineering design work and invention of the Super Soaker.[5]

On the final day enacting this lesson, the teacher engaged students in an interactive read-aloud of the other paired text, a trade book entitled *Whoosh! Lonnie Johnson's Super Soaking Stream of Inventions* by Chris Barton. In addition to engaging students in discussing the ideas in the text and making connections to the previous reading and video, the teacher challenged students to describe Lonnie Johnson's traits (e.g., hardworking, creative, curious) and how these traits were revealed through his actions in the book. The enactment timeline, in the table below (5.1), illustrates the flow and timing of activities across the three days of instruction described.

Table 5.1

Lonnie Johnson Text Set Enactment Timeline

Lesson	Day	Lesson Activities
Lesson 2.4: How did Lonnie Johnson design the Super Soaker?	Day 1 45 mins.	• Teacher introduced and demonstrated a variety of water squirters, including the Super Soaker • Students observed and identified parts of the systems, made predictions about how the parts worked together, and made predictions about which water squirter would shoot water the farthest • The class collaboratively designed and conducted fair tests to investigate which water squirter would shoot water the farthest
	Day 2 45	• Teacher introduced Lonnie Johnson as the engineer who designed the Super Soaker • The teacher revisited the Driving Question and enacted an interactive read-aloud of the biographical text, *From Water Squirter to Super Soaker: How Lonnie George*

[5] During this discussion two students asked permission to study Lonnie Johnson for their independent projects. The students completed several independent or partner projects throughout the schoolyear, which included selecting a topic of interest that they would like to share with their classmates, researching information (or "facts," as the students and teacher often described this) using books and online resources, and preparing a presentation to share with their classmates.

	mins.	*Johnson changed water games* • Students viewed a video clip of Lonnie Johnson and discussed connections to the engineering design process
	Day 3 50 mins.	• Teacher engaged students in an interactive-read aloud of a trade book about Lonnie Johnson, *Whoosh! Lonnie Johnson's Super Soaker Stream of Inventions* • Students identified Lonnie Johnson's traits and how his actions in the book revealed these traits

Testing Conjectures

In analyzing and reporting data specific to the design and enactment of the *Lonnie Johnson text set* and engineering task, I foreground the following features of the designed MLs learning environment (i.e., *embodiment*): (a) the designed tools and materials, including teacher supports (i.e., lesson plans, interactive reading guide) and multimodal literacy resources (i.e., researcher-designed text, trade book, video); and (2) the task structure. The *mediating processes* outlined in my conjecture map served as analytic lenses, guiding my analyses of enactment data, artifacts, and interviews. For instance, to understand whether and how the *mediating processes* produced *desired outcomes* within this lesson, I drew on transcript and interview data in order to closely analyze the ways in which the *mediating processes* emerged and unfolded in the classroom.

The close analysis of transcribed video of lesson enactment allowed me to analyze the ways in which the designed tools and materials (e.g., teacher supports, literacy resources) and task structure produced observable interactions: (a) using tools of reading, writing, viewing, and discussing for meaningful purposes, (b) using scientific ideas and practices, (c) building on prior knowledge and funds of knowledge, and (d) the teacher's instructional moves. Analyzing observable interactions revealed within transcript data in combination with interview data, allowed me to examine whether and how the *mediating processes* led to *desired outcomes*, including: (a) making sense of and synthesizing multimodal texts and (b) using science ideas and practices to make sense of an explain phenomena. I present my findings in the following section.

Findings

In this section, I present findings from my analyses of enactment data (lesson plans, field notes, and transcribed video recordings) and interview data with focal students and their teacher to respond to my research questions: (1) How did the design and enactment of the *Lonnie Johnson text set* and task support third-graders' science and literacy learning? (2) How might modifications to the design of the texts and task better support third-graders' science and literacy learning, in the context of project-based science instruction?

Findings from enactment. I found that the design of the text and tasks, and the teacher's enactment of *From Water Squirter to Super Soaker*, and paired texts, synergistically supported third-graders' science and literacy learning. I also identified missed opportunities, both within the design of the curriculum resources and the enactment of the lesson, for further supporting the science and literacy learning of all students.

As suggested in the lesson plan, the teacher engaged students in first-hand experiences to build background knowledge prior to reading, and to set a purpose for reading. To launch this lesson, as suggested in the lesson plan, the teacher showed students the water squirters and Super Soaker and then asked students to talk about what they knew about them or what they noticed, and then demonstrated how the toys worked. During this part of the lesson (Day 1), the teacher provided opportunities for students to engage in scientific and engineering practices as they made observations, identified parts of the systems of the water squirters and Super Soaker, and made predictions about which would squirt water the farthest and explained their thinking.

Instead of simply demonstrating the toys, as suggested in the lesson plan, the teacher chose to engage students in collaboratively planning and conducting a brief investigation, using fair tests.

Thus, while the written curriculum proposed that students only briefly make and share observations of the water squirters and Super Soaker (during a 10-minute introduction to the lesson), the teacher chose to dedicate a full day of science instruction (45 minutes) to observing and investigating these toys. These opportunities allowed students in the class to build shared knowledge and experiences about the design and function of water squirters and the Super Soaker prior to reading and viewing, which the teacher later supported them to draw upon to promote continued knowledge-building as students read and viewed the Lonnie Johnson text set. In the end-of-unit interview with the teacher, she emphasized the important role of engaging students in these firsthand experiences with the Super Soaker prior to reading:

> I think having the actual Super Soakers visually there and doing the demonstration… made the book that much more interesting. I really do. I think anytime they can see that (in) real life and then see it in a book just magnifies that…it's not just words on a page… There's meaning there, there's a story there, (and) there's something to learn from it.

Table 5.2, below, provides illustrative examples (from Day 1 transcripts) and descriptions of how the teacher supported students to build background knowledge prior to reading by engaging them in first-hand exploration and scientific practices.

Table 5.2

Building Background Knowledge Through First-Hand Experiences

Transcript Excerpt	Description
T turns to a black sheet of chart paper. T begins drawing on the chart paper. A student is holding up a water squirter on the kidney table for the teacher to draw. T continues drawing. One students said, "It's a rocket." Another student says it looks like an upside-	In this excerpt, from the beginning of the lesson (Day 1), the teacher brought the water squirters and Super Soakers out into the classroom and invited students to make observations of the toys. After a few students shared observations, the teacher introduced the goals

down plunger… T says that their goal is to go outside and demonstrate these "water rockets" … T says they are going to talk about all of the toys and then take some time to go outside and test them. (Field Notes, Day 1)	for the day: demonstrating and testing the toys. This excerpt shows how the teacher set a purpose for the lesson. These tasks provided students with shared first-hand experiences with the toys to which they could connect during later reading and viewing.
Teacher: Okay, how about this one. What do you notice about this one? **Lucas:** You have to get water and then fill it up and then it's like a pump. **Teacher:** Okay, so can I say like a water pump? Malik? **Malik:** Air comes out of it. Wait, I mean, air does not come out of it. **Teacher:** Okay, tell me more about what you mean by that. **Malik:** If you pump that, air will not come out. **Teacher:** If I pump this, air would not come out? What make you think air is not coming out? I'm going to let you come here. Well, stay right there. Is there air coming out? **Malik:** Yes. **Teacher:** Okay, can you tell me something about what it does or what it looks like? **Malik:** When you pull the yellow part and you put it back in, it goes back and forth and air comes out of it. (Day 1)	In this excerpt, the teacher invited students to make observations of one of the water squirters. Lucas provided the first observation in this excerpt, describing how the water squirter works. Malik followed with an observation about whether or not air would come out of the water squirter when pumped. The teacher followed up with Malik's original observation through questioning, engaging Malik in a hands-on exploration of the toy, and pressing Malik to clarify his ideas. Field notes and transcripts revealed that, during this portion of the lesson, a total of 14 students in the class had the opportunity to share their observations of the toys during whole-class discussion, which contributed to students' shared knowledge-building and first-hand experience.
Teacher: Which one do you think may squirt the farthest? (*Students vote on which water squirter they think will shoot the water the farthest by raising their hands. T counts votes. The majority of students think that the long tube water squirter will shoot water the farthest.*) **Teacher:** Let me ask you this, because we are talking about engineering and we are talking about making toys that other kids can build, anybody have a reason why they think why might this be the most? Why might more people think this? **Jenna** notices the sticker that says it shoots over 40 feet. **Julia** also notes the stickers that advertise how far it shoots. **Teacher:** Okay, so the stickers are kind of appealing to you, telling you it might shoot far. **Kayla:** Because that's the longest one and if its longer it might absorb more water. (Day 1)	In this excerpt, the teacher asked students to predict which water squirter would shoot water the farthest. Making predictions is an important element of NGSS Practice 1 Asking Questions and Defining problems: "Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships" (NGSS Appendix F, p. 4). In response to the question about which water squirter would shoot the farthest, students shared their prediction through a raise of hands and were pressed to explain their thinking. This excerpt illustrates the ways in which students' first-hand explorations, on Day 1 of the lesson, served dual purposes of engaging students in scientific practices and building prior knowledge and shared experiences that could be drawn upon to support comprehension during later reading and viewing. Following this excerpt, the class worked together to collaboratively plan and conduct an investigation to test their predictions and determine which water squirter shot water the farthest distance.

The teacher leveraged opportunities for students to make connections to prior knowledge and experiences, including but not limited to the suggestions in the reading guide. Having provided opportunities for students to build background knowledge before reading by engaging in first-hand explorations of the water squirters and Super Soaker on Day 1, the teacher leveraged these and other shared experiences from the unit to support students' learning with the

Lonnie Johnson text set on Days 2 and 3. In addition to supporting students to make connections to their experiences observing and investigating the water squirters and Super Soaker, the teacher also supported students to make connections to their first-hand experiences building their own toy prototypes, as well as to their experiences interviewing kindergartners for feedback and suggestions about how to improve the toys they built. Reading instruction that engages students in drawing on their prior knowledge and experiences as they read, supports comprehension (e.g., Brown et al., 1996; Saunders & Goldenberg, 1999).

Explicitly linking the students' Lonnie Johnson text reading and viewing to prior unit experiences and reading for the purpose of later applying the engineering design practices illustrated in the text to improving students' own designs, created a meaningful purpose for students' reading and viewing. Together, these opportunities created coherence between students' reading and viewing and other unit experiences, which supported students to continue building knowledge about core science and engineering ideas (e.g., force and motion) and practices (e.g., engaging in engineering design), to reflect on their own experiences engaging in scientific and engineering practices, and to connect their reading and viewing to the work they would do later in the unit. This echoes Purcell-Gates et al. (2007) findings that opportunities for second- and third-grade students to engage in meaningful reading experiences (e.g., reading for purposes beyond simply learning to read), in the context of science instruction, were associated with greater comprehension gains than were more traditional school-based literacy activities. Table 5.3, below, provides illustrative examples from Days 2 and 3 transcripts and descriptions of how the teacher supported students to draw on prior knowledge and experiences to support their interpretation of ideas in text and video.

Table 5.3

Connecting to Prior Knowledge and Experiences

Transcript Excerpt	Description
Teacher: Think about anything we've done in, I don't know, the last four or five days that might have something to do with this article that we're about to read, Cameron? Can you pass it (*the microphone*) to Cameron please? **Cameron:** We shot some of those. We shot the Super Soakers. **Teacher:** Where did we shoot them at? **Cameron:** Outside the cafeteria. **Teacher:** Okay, and what were we hoping to find out? **Cameron:** How far they go. **Teacher:** Okay, how far they would go. How many different ones did we look at, do you remember? **Cameron:** Three. **Teacher:** We looked at three different ones. For those of you who weren't here, that was my making a drawing. So, we had 3 different Super Soakers and we went outside behind the cafeteria and prior to that, we made some observations, we thought about how they might work, and then we went outside and we tested them. (Day 2)	In this excerpt, in preparation for reading the researcher-designed text, *From Water Squirter to Super Soaker*, the teacher prompted students to recall their shared experiences of observing and testing the water squirters in class. In this exchange between the teacher and Cameron, the teacher asked a series of questions about what the class did, during Day 1, and Cameron described the class' experiences, as the rest of the class listened. This excerpt concluded with the teacher revoicing and adding to Cameron's recap to prime students to be thinking about these experiences as they began reading on Day 2.
Teacher: (*reading aloud)* "He built a prototype…" Think about your toys, alright. Think about your toys. They're kind of like prototypes, "which is a first model…onto something big." (Day 2)	This brief excerpt illustrates one way in which the teacher prompted students to make connections, while reading, to their first-hand experiences in the unit. In this case, as the teacher read about Lonnie Johnson's Super Soaker prototype, she prompted students to think about the prototype toys they built in class.
Teacher: What was a system or what was something that he found interesting that he kind of used with his robot? He used it with his robot to get his robot to move. **Student:** Force. **Ellie:** Compressed air. **Teacher:** Compressed air. Think about what we did on Friday. Do you think we were using any compressed air on Friday? **Lucas:** Yeah, loads of it. (Day 2)	In this excerpt, the teacher posed a question about ideas in the text. Ellie responded that Lonnie Johnson had used compressed air with his robot. At this point, the teacher prompted students to reflect on whether they used compressed air as they explored the water squirters in class. One student, Lucas, responded affirmatively, suggesting that he made this connection and understood the teacher's reference. However, because this exchange ended here, it is likely that not all students in the class made the connection between compressed air in Lonnie Johnson's robot and their experiences with compressed air testing the Super Soaker, since a more complete explanation was not provided.
Teacher: Okay, (*reading aloud*) "…his design…water is drawn into the chamber." Think about this one that we did or actually both of these (*water squirters that students observed and tested outside*). What did we have to do with both of these kinds of blasters? **Student:** We had to pull something. **Teacher:** You had	In this excerpt, after the teacher read about the design of the Super Soaker and how it worked in *From Water Squirter to Super Soaker*, the teacher pointed to two of the water squirters students explored in class and prompted students to make compare the information in the text to how the toys they tested worked. This provided students with an opportunity to, not only, read

to pull it back, right? Alright, as you were pulling it back, what was happening? **Student:** It was sucking in. **Teacher:** It was sucking water in, right? And then what did we do? **Student:** Blast it. (Day 2)	about how the Super Soaker worked in the text, but to draw on the experience of actually using the Super Soaker in class.
Teacher: Did Lonnie Johnson go through an engineering process or a design process? **Students:** Yes. **Teacher:** Okay, for most of you I heard yes. What makes you think yes? If these are some of the steps (*written on the board as students shared out ideas*), what makes you think that he went through that process, Cameron? **Cameron:** How could he build it if he didn't like plan it or like imagine it being built? **Teacher:** Okay, so how could he possibly have planned it if he didn't imagine how he was going to build it or plan what he was going to do? Ellie. **Ellie:** I have something for that (*list of engineering design practices/process*) to add. **Teacher:** Okay. **Ellie:** Communicate. **Teacher:** Communicate somewhere. **Ellie:** Like get feedback when you're… **Teacher:** Communicate and you're saying that's kind of like feedback? **Ellie:** Yeah. **Teacher:** When she says communicate and feedback, does that make you think anything? Does that make you think of anything, Owen? **Owen:** Kid President. **Teacher:** Okay, the Kid President video that you watched. **Owen:** He had to go and ask like how can I make this thing. **Teacher:** How can I make this? Does it make you think of anything else kind of closer to home? If we're talking about communicating and feedback? …Have we done any kind of communicating or feedback? **Students:** Yeah! **Teacher:** When? **Students:** When we made our toys. **Teacher:** You made your toys and then what? **Students:** What asked the kindergartners. (Day 3)	This excerpt begins with the teacher asking students if Lonnie Johnson used the engineering design process as he designed the Super Soaker. Many students responded affirmatively and the teacher followed by asking them to explain their thinking and referenced the student-generated list of practices engineers use as they design. Cameron suggested that Lonnie Johnson would have had to imagine and plan before he could have built the Super Soaker. Ellie, then, interjected with a proposed addition to the class' notes about the engineering design process: Communicate and get feedback. After adding this suggestion to the ideas on the board, the teacher asked the class if this addition made them think of anything else they had done so far in the unit. One student, Owen, shared that this reminded him of a video clip the class watched about a child who sought feedback from professional engineers after creating his own inventions. When the teacher pressed for additional connections, another student suggested that the idea of communicating and getting feedback in the process of designing solutions reminded them of when they made their toys and interviewed the kindergarteners. This excerpt illustrates the ways in which the design and enactment of the texts and related tasks worked in hand with other PBL unit experiences to create a seamlessness between students' first-hand and text-reading or viewing experiences. I argue that this seamlessness in the design of the written curriculum, and the teachers' work to make these connections explicit for students, supported students' science learning and sense-making with text, in this unit.

Beyond the suggestions provided in the written curriculum, the teacher modeled and encouraged students to use reading strategies. For the Lonnie Johnson text set, the written curriculum materials did not provide suggestions to the teacher related to modeling or supporting students to use reading strategies to support text comprehension. However, the teacher frequently did this during the interactive read aloud of both the researcher-designed text (*From Water Squirter to Super Soaker*), the video, and the trade book (*Whoosh!*) about Lonnie Johnson. For example, the teacher engaged students in making predictions both prior to and during reading and also modeled and prompted students to make text-to-self and text-to-text connections as they read and viewed. The teacher paused frequently during interactive readings to ask students to relate the ideas in the text to their own thinking, feelings, and experiences.

Additionally, the use of a text set (e.g., researcher-designed text, video, and trade book) in this lesson, created opportunities for the teacher to support students to make connections across texts as they read and viewed. However, the written curriculum did not directly support this instruction. Analyses revealed missed opportunities with respect to supporting students to synthesize information across multiple texts, which are described in the table below and are addressed further in a later section. Table 5.4, below, provides illustrative examples from Days 2 and 3 transcripts and descriptions of how the teacher modeled and supported students to use reading strategies to support their interpretation of text.

Table 5.4

Modeling and Using Reading Strategies

Transcript Excerpt	Description
Teacher: So, *From Water Squirter to Super Soaker*. Why do you think it goes from squirter to Super Soaker? Any predictions on that? Aiden? **Aiden:** Because he could have changed, because he changed the, because he made a water gun that can wet somebody pretty bad. **Teacher:** Okay, so which would you want to play with, a squirter or a super soaker? **Student:** Super soaker, obviously! **Teacher:** Why would you? Okay, you say obviously. Why would you rather play with a Super Soaker, obviously? Lucas? **Lucas:** Because it would soak you down and cool you off. **Teacher:** Right, just the word soak, you know that you're probably going to drench somebody. (Day 2)	In this excerpt, the teacher asked students to make predictions about the text based on the title, *From Water Squirter to Super Soaker.* Aiden shared his prediction about what the title might mean and then the teacher continued to talk with other students about what the words in the title, like "soak" suggested about what they might learn as they read the text.
Teacher: Not that long ago, right? I was alive then (*in 1991*)! (*reading aloud*) "…when the Super Soaker went on sale. With the Super Soaker, you could drench someone with a single blast of water." And I will tell you, when we used to do canoes like up and down the rivers with friends, everybody wanted to make sure they had a Super Soaker. **Students:** Why? **Teacher:** Because if not, oh, they were going to get soaked and	In this excerpt, the teacher paused, as she read aloud, to model a text-to-self connection. Here, the teacher shared a brief anecdote about her own experiences with Super Soakers when she was young. After sharing this personal story in connection to the information in the text, the teacher explained that it can be useful to make connections to other things, such as your own experiences, while reading. This is one illustrative

they had no retaliation, alright? So, I'm just making that connection. Whenever you're reading, it's always a good idea, if it makes you think of something else, just kind of say that to yourself. (Day 2)	example, of many, text-to-self connections that the teacher modeled and supported during the Lonnie Johnson text set.
Teacher: (*reading aloud*) "Everyday brought a challenge for…Mobile, Alabama." Did we know yesterday that he had five brothers and sisters? **Students:** No! **Teacher:** No. So, you're definitely going to get more information about him in this, which may allow us to come up with some more traits about what kind of person he is. (Day 3)	In this excerpt, as the teacher engaged students in an interactive read aloud of the trade book, *Whoosh!*, she asked students to reflect on what they learned from the researcher-designed text and video the previous day. She prompted students to notice that the trade book, not only repeated some information they had already learned about Lonnie Johnson, but would also provide new information about Lonnie and his work as an engineer. In this context, the teacher could have further supported students to synthesize, or compare and contrast the information, presented across the texts and video about Lonnie Johnson. This text set could have provided an opportunity to explicitly scaffold students' skills relative to comparing and contrasting information in multiple texts on the same topic.
Teacher: (*reading aloud*) "His dream had been challenged…Linex." Who is Linex? **Students:** The robot! **Teacher:** The robot. Do you remember what parts the robot was made out of? **Students:** A jukebox. The tape. Walkie talkie. His sister's tape. (Day 3)	In this excerpt, the teacher prompted students to recall information form the researcher-designed text (Day 2), to inform their sense-making as they read the trade book on Day 3. Specifically, when the teacher read about the robot, Linex, in the trade book, she asked students to recall the materials Lonnie used to build this robot, which were described in the researcher-designed text (described in words and represented in images). This provides one example of how the teacher supported students to draw on information across multiple texts and multimodal information to support their sense-making during reading.
Teacher: (*reading aloud*) "For a water battle to be a fair fight…after toy company." **Student:** After toy company. **Teacher:** And what did they all say? **Students:** No. **Teacher:** Do you think he said, alright, I'm just not going to do this? **Student:** No. **Keyanta:** He never gives up! (Day 3)	In addition to engaging students in making predictions prior to reading, the teacher also paused on different occasions during reading to pose questions and prompt students to predict what might happen next in the text. In this example, the teacher asks whether, based on events in the text, Lonnie would give up on designed the Super Soaker.

As suggested in the lesson plan and reading guide, the teacher used the texts to illustrate engineering practices and core ideas. During Days 2 and 3 of instruction, the teacher leveraged Lonnie Johnson's engineering design work with the Super Soaker, as described in the readings and video, to illustrate engineering practices and core ideas. After reading the researcher-designed text and viewing the video about Lonnie Johnson's work as an engineer, the lesson plan suggested that the teacher ask students to talk about Lonnie's work as an engineer and to describe practices or process engineers use as they design, based on students' prior knowledge and information in the reading and video. The interactive teaching guide for the researcher-designed text highlighted examples of how Lonnie Johnson used the engineering design process, but did not suggest discussion questions or prompts useful for engaging students in identifying these examples or connecting them to their own engineering design work in the PBL unit. However, the teacher provided the students with opportunities, both during and after reading, to discuss engineering practices and make connections to their own engineering design work, as they read and viewed. The table below (Table 5.5) illustrates these opportunities.

Table 5.5

Introducing and Illustrating Engineering Practices and Core Ideas

Transcript Excerpt	Description
Teacher: So, what was he? What was his job? **Students:** Engineer. **Teacher:** He was an engineer. What's the first part of the engineering process? **Lucas:** Making stuff. **Student:** Plan. **Owen:** Ask. **Teacher:** What do you mean, ask? **Owen:** Like, as yourself how can I build this thing. **Teacher:** How can I build this thing? Okay, Keyanta? **Keyanta:** I would say college first. **Teacher:** Okay, well that's not part of…that would certainly be a step you would want to take to get an engineering degree, but when you're talking about the engineering process, we usually have to…before we even ask, what do we have to do before that? **Student:** Plan. **Teacher:** Before planning, you guys definitely have the parts of it. Nick? **Nick:** Imagining. **Teacher:** Before even imagining. What are you missing? What are you trying to ask a question about? What are you trying to make a plan for? Ellie? **Ellie:** Get inspiration. (Day 2)	In this excerpt, the teacher leveraged students' experiences with reading and viewing the Lonnie Johnson text set to engage students in a discussion to identify and describe the parts of the engineering design process. Lonnie Johnson's work designing the Super Soaker and other inventions, provided a shared example and opportunity for students to co-construct important engineering practices and the parts of the process that practicing engineers draw upon in their work. In this excerpt, several students shared their thinking about how engineers begin the process of designing a tool or solution.
Teacher: How can we tie this into our, what we're doing in science? What's our driving question or…? Ellie? **Ellie:** How can we design inexpensive or fun moving toys that other kids can create? **Teacher:** Okay, so what's that part of in science? Okay, creating. What else? **Ellie:** Engineering. **Student:** Lonnie Johnson, he created something with just parts that he found. **Teacher:** Okay, so kind of scrap parts. Alright.	In this excerpt from Day 3 of this lesson, after the teacher and students discussed important parts of the design process illustrated in the Lonnie Johnson text set, the teacher asked students to connect their learning to what they were doing in the larger PBL unit and the unit Driving Question. This provided an opportunity for students to connect to their own experiences, and also launched continued conversation about steps of the

(*T makes notes about student ideas on the board.)* I heard you say something, Ellie. What did you say? **Ellie:** The engineering design process. **Teacher:** Okay, so the engineering design process. What do you know about the engineering design process? (Day 3)	engineering design process, that students would then use to move forward their designs of moving toys. Following this excerpt, five additional students shared what they already knew about the engineering design process.
Teacher: So, again, think about that engineering design process. Think about where we're at in the engineering design process with our toys. **Student:** Improve. **Teacher:** We're kind of making the improvements and going back to plan, right. I think the last thing…you guys did was you started to draw what you would do, how you would make your new toy with one of the changes. (Day 3)	This excerpt, from Day 3 of this lesson, illustrates how the teacher continued to leverage the Lonnie Johnson text set to support students' thinking about the engineering design process. The important contribution of this excerpt, however, is that it shows how the teacher connected students' learning about the engineering design process in this lesson to supporting students' thinking about how they would apply engineering design practices to the design and improvement of their own toys.

The teacher used the tasks, the texts themselves, and suggestions in the reading guide to reinforce, introduce, and clarify vocabulary. The use of text in the context of science instruction can provide opportunities to reinforce, introduce, and clarify vocabulary, particularly Tier 2 and Tier 3 words (Beck, McKeown, & Kucan, 2002), which are important for building and communicating disciplinary knowledge. Beck and colleagues developed a heuristic, which organized vocabulary words by tier: Tier 1 words are those which are the most basic and are typically learned without instruction (e.g., play, sad, rocket); Tier 2 words often require instruction and are useful for communicating across academic domains (e.g., transmit, system); Tier 3 words are often the most difficult, abstract, and discipline-specific (e.g., force, compressed). Before and during reading the researcher-designed and trade book texts about Lonnie Johnson, the teacher leveraged opportunities to reinforce, introduce, and clarify Tier 2 and Tier 3 words within the texts and the larger unit of instruction, such as force, compressed air, and transmitter.

In some cases, the teacher used background knowledge-building activities (Day 1 of instruction) to revisit and reinforce important vocabulary and scientific ideas from the larger unit of instruction (e.g., force). In other examples, the teacher drew on suggestions from the reading guide to unpack and clarify vocabulary introduced in the text (e.g., compressed air). Finally, some students directly asked about the meaning of particular words in the text (e.g., transmitter). Table 5.6, below, provides illustrative examples of these instances and the ways in which the teacher and students took up these kinds of opportunities during instruction. The table also identifies possible missed opportunities for ensuring that all students developed a common understanding of important vocabulary for understanding the ideas in the texts.

Table 5.6

Introducing, Reinforcing, and Clarifying Vocabulary

Transcript Excerpt	Description
The teacher asks students to share their observations of the different water squirters. **Aiden:** That if you pull that back, the yellow part… **Teacher:** What did you say? **Aiden:** If you pull the yellow part. **Teacher:** What did you say? **Aiden:** If you use a force to pull the yellow part back. **Teacher:** You could have just kept saying pull, but it's great that you made that connection. *Additional students make observations. One student observes that all of the water squirters suck up and use water.* **Teacher:** So, they suck up and use water. Anything else? Cameron? **Cameron:** You use a force to pull it back under the water and the use another force to push it back so that the water comes out. **Teacher:** Are you saying that on all of those? Okay, so on all of them there's a force use to pull up, did you say water? **Cameron:** Yeah. **Teacher:** Or pull in water and then spray it out. **Cameron:** Spray it out. **Teacher:** So, we'll kind of put "all" here (*referring to the observation notes written on the chart paper*). Anything else you may notice about all of them? **Ellie:** You have to pull something. For each of them, you have to pull something or use a force. (Day 1)	In this excerpt, the teacher challenged Aiden to use science vocabulary (e.g., force) that the class was learning about in the unit as he shared his observations of the water squirters on Day 1 of this lesson. As students continued to make observations, they also took up the opportunity to use the term "force" in their observations.
Teacher: Alright, let's keep reading. Lots more interesting stuff to read about Lonnie Johnson. "Lonnie designed the robot to move using compressed air." What do you think compressed means? Can you show me what compressed means? Lucas' got it. Owen's got it. Compressed. Compressed air. Alright, hold tight.	In this excerpt, as the teacher read the researcher-designed text aloud with the class, she paused to ask the class what they think compressed air means and if they could show what it means with their hands. At this point in the text, the interactive reading guide suggested pausing the reading to engage students in a

Clearly, I'm not telling you anything you don't already know! *The teacher continues reading the researcher-designed text aloud with the class and pausing to discuss the ideas in the text. After reading further, she pauses to revisit the idea of compressed air.* **Teacher:** We talked a little bit about that compressed air. That's really kind of important. Can anybody give an example of how we can show compressed air? Kaylee? Cameron? Okay, think about a balloon. **Student:** It's like a rocket. **Teacher:** Think about a balloon. **Student:** If you let it go, it flies through the air. **Teacher:** But what does that air do to that balloon? **Student:** Compresses it. **Teacher:** Well, it makes that small balloon a lot bigger, right? So that air is kind of compressed and you hear that word 'pressed' in there… What happens if you don't tie that balloon and you let it go? **Curtis:** It floats into space. (Day 2)	demonstration of blowing up a balloon and discussing the meaning of compressed air through this demonstration. Providing this opportunity would have provided additional opportunity for students who might not have made this connection during this exchange, to visualize and describe the meaning of compressed air. Later in the interactive read aloud, the teacher returned to the idea of compressed air, and asked students if anyone could give an example. When no students volunteered, the teacher described, but did not conduct, the demonstration suggested in the teaching guide. Again, while the additional information and example may have further supported students' understanding of this concept, providing a first-hand experience with compressed air in a balloon might have better supported the learning of all students.
Ellie: What's a transmitter? **Teacher:** A transmitter, can anybody tell Ellie? Lucas? **Lucas:** A transmitter is like, it transmits the data it wants to tell it to do and puts it into a different thing. It's like the Internet but all in a control or something. **Teacher:** Okay, so if you transmit something, you kind of used the word to explain the word, which happens a lot. But you're saying it transmits. What's another word you could use for transmits, Lucas, since you gave it? **Lucas:** It flows. **Teacher:** Okay, it flows, or can anybody else think of another word? **Keyanta:** It kind of processes. It goes back to the word and then it hears it and then it does it. *The teacher and students continue to co-construct a definition and examples of what it means to "transmit" something.* (Day 3)	This excerpt provides an example in which a student identified and asked about an unknown word that appeared in the trade book, "transmitter." In this context, the teacher asked if other students could explain or provide examples of what it means to "transmit" something. Together, the teacher and multiple students worked to co-construct the meaning of this term.

The teacher used the paired text set and suggestions within the written curriculum to reinforce relevant CCSS for ELA. In concert with supporting students to build knowledge with respect to important science and engineering ideas and practices, reading, viewing, and interpreting multimodal, biographical text about the life and engineering work of Lonnie Johnson provided opportunities for the teacher to reinforce specific grade 3 reading standards for informational text and literature (*CCSS for ELA*). Opportunities for students to interpret words in text (RI.3.4) were described previously. In addition to word learning opportunities, the texts and tasks in this lesson provided opportunities for students to integrate information from the words and images in text to interpret meaning (RI.3.7), and also to use text evidence to describe characters (in this case, Lonnie Johnson is a real person) in text and to explain how their actions contribute to the sequence of events in the text (RL.3.3). This finding is important because it illustrates the potential for texts and tasks in project-based science to be designed for the dual purposes of supporting students' science and literacy learning, as illustrated in Table 5.7.

Table 5.7

Reinforcing CCSS for ELA

Transcript Excerpt	Description
Teacher: Then it says, "Can you tell how he used the reels he got from his sister's tape recorder?" (*T points out the photographs in the text and describes what a juke box and tape recorder are.*) …But the question was can you tell how he used the reels? These are the reels (*pointing to the photograph in the text*) he got from his sister's tape player. What did he use the reels for? Makayla, what did he use the reels for? He used it for the eyes, right? (Day 2)	This excerpt provides an example of how the teacher provided opportunities for students to combine illustrations and words in a text to make sense of ideas in the text. As illustrated here, the text was designed to prompt students to engage in the work of integrating information from words and images through providing the embedded question within the text: "Can you tell how he used the reels he got from his sister's tape recorder?" While this was prompted, this excerpt reveals that instead of having students pause to discuss the images and words in the text, in this case, the teacher quickly made this connection for students before continuing to read the text. This has implications for the design of teacher supports within the written curriculum, which I describe in the conclusion.
Teacher: Just based on what we've read, what you've listened to, what kind of a person do you think Lonnie Johnson is? What kind of person? What words would you use to describe him? Lucas? **Lucas:** A very creative person. **Teacher:** Okay, so creative. What else would you say about Lonnie Johnson, Kayla? **Kayla:** Inventor. **Teacher:** Inventor (*recording student ideas on board*). Jenna is your hand up? Oh, it was Aiden. Aiden? **Aiden:** An engineer. *Other ideas provided by students, as this discussion progressed included "unique, someone that fixes, and a handyman."* (Day 2)	In this excerpt, the teacher paused, after reading a portion of the text, *From Water Squirter to Super Soaker,* to invite students to describe Lonnie Johnson's character. This was suggested in the written curriculum and reinforced grade 3 CCSS reading standards. As they read the text, the teacher compiled a list of the descriptive words and phrases students used to describe Lonnie's character based on information in the text throughout the lesson.
Teacher: (*reading aloud*) "Science fairs came and went…and then another until…" So, I'm already thinking, what's one character trait that you could say about him? **Ellie:** He misses a lot of stuff. **Teacher:**	Similar to the previous excerpt, the teacher continued the identification and discussion of Lonnie's characteristics as students participated in the interactive read aloud of the trade book, *Whoosh!* While the

Owen? **Owen:** Hardworking. **Teacher:** Okay, hardworking. Aiden? **Aiden:** Determined. *T and students continue talking about other ways that they could describe Lonnie's character based on the information in the text (e.g., "loves technology, does not stop until he finishes, perseverance").* (Day 3) *After reading, students worked with a partner, to identify descriptive words that characterized Lonnie Johnson, based on evidence from the book.* (Day 3)	teacher provided multiple opportunities for students to describe Lonnie's characteristics, these opportunities could have been enriched by pressing students for text evidence in support of their descriptions of Lonnie's characteristics in the context of discussion. Further, the trade book used a number of descriptive words in characterizing Lonnie, but the class did not pause to discuss these (e.g., self-confident, insightful, creative thinking), despite their overlap with students' ideas.

Constraints of the text and task revealed through enactment. In addition to the ways in which the text and task supported students' science and literacy learning, my analyses also revealed limitations of the design and enactment of the written curriculum. One limitation is that, while many students had opportunities to share their observations and noticings about the parts of the water squirter systems, to make and share predictions about which water squirter would shoot the farthest, and to directly participate in planning and conducting the water squirter investigation prior to reading, this was not true of all students. Similarly, though the teacher sampled many students' ideas as they discussed the Lonnie Johnson text set and supported students to make connections to firsthand and other unit experiences, this does not guarantee that every student in the class was "on the same page" with respect to making such connections.

Moje et al. (2001) found that the written curriculum and the teachers' enactment of one middle school project-based science did not scaffold all students' participation in the oral discourses of the classroom, and their engagement in deep science learning. While my analyses of enactment data suggest that some of the third-graders, particularly those students who struggled with reading, appeared to be left out of some class discussions, student interviews provided some evidence (see below) that these students were still engaged in the work of making meaning during text reading and related literacy tasks, despite not sharing their thinking with the class during discussions.

Based on enactment data alone, however, it is impossible to know whether or how some students took up the literacy and science learning opportunities provided. Because of this limitation, we began to explicitly identify opportunities for the teacher to scaffold all students' sense-making discussions with peers through use of multiple participation structures, and to design opportunities for students to make digital written entries in response to many of the texts included in the curriculum. The technology tools that students use in *MLs* enables, not only the capability of embedding response boxes within the digital texts, but also affords students the opportunity to collaboratively enter responses with peers and share these ideas with the teacher and classmates in real time. Designing curriculum materials and tasks that support the teacher to enact PBL lessons such that they bring all students into sense-making conversations with text to support science and literacy learning continues to be an aim of the MLs project.

Another limitation revealed through enactment were missed opportunities to push student reasoning and thinking, in the context of reading and discussing information in multiple, multimodal texts. While analyses revealed that the lesson plan, the texts themselves, the interactive reading guide, and the teacher's enactment worked synergistically to support students' science and literacy learning, I also identified instances in which the written curriculum failed to provide suggestions that might have extended student learning, such as suggesting that students draw evidence from the text to support their ideas or highlighting for the teacher, key ideas across multiple texts on the same topic. Analyses also revealed opportunities, seeded in the written curriculum, that the teacher did not take up during enactment, such as engaging students in the demonstration with the balloon to illustrate the idea of compressed air. If enacted, this opportunity may have served to extend students' opportunities to understand the meaning of this term and was important for understanding the parts of the Super Soaker system and function.

Because of this limitation, we began to design more suggestions within the interactive reading guides for specific discussion questions that teachers may pose in order to engage students in rich discussion about ideas within single, and across multiple, texts.

Findings from student interviews. In this section, I describe findings from interviews conducted with focal students that provided additional insights about students' science and literacy learning in the context of reading, viewing, and discussing the Lonnie Johnson text set, with a specific focus on the researcher-designed text, *From Water Squirter to Super Soaker*. The interview protocol consisted of a subset of questions from a larger interview protocol, which contained questions about all texts included in the unit of instruction. Questions specific to the Lonnie Johnson texts, addressed here, included: (1) What do you remember about this text (researcher-designed, *From Water Squirter to Super Soaker*)? and (2) How did reading about Lonnie Johnson help you understand more about what engineers do?

The interview was conducted a month after the students read the Lonnie Johnson text set and was designed to explore what students recalled about the text, and how reading about Lonnie Johnson helped them understand more about engineering design. I first report how the students responded to the open-ended question specific to what they recalled about reading the researcher-designed text, and then report on how students text helped students understand more about what engineers do.

Fourteen of the sixteen focal students interviewed reported that they remembered reading the text. When asked what they recalled about the text, twelve students recalled that Lonnie Johnson designed the Super Soaker and other inventions. Three students recalled the design problem introduced in the text (i.e., because water squirters were not very powerful, they did not get people very wet). Finally, seven students recalled parts of the engineering design process that

Lonnie Johnson used as he created the Super Soaker. Testing and gathering feedback about the Super Soaker's design was particularly salient for some of the students interviewed (Table 5.8).

Table 5.8

What Students Recalled About the Text

Findings	Examples from Interview Transcripts
Students recalled the design problem introduced in the text	Aiden: "…a water squirter did not give enough water to actually have fun but it was a good way to cool down, and you could drench someone with a single blast of water with a Super Soaker."
	Christian: "That he (*Lonnie Johnson*) didn't want a water soaker anymore, so he made a Super Soaker…so it could drench people when kids were having a water fight."
	Owen: "That, when it was in the summer, they were using some just little water guns and they weren't getting soaked."
Students recalled that Lonnie Johnson invented the Super Soaker and other inventions	Brandon: "…he (*Lonnie Johnson)* wanted to make toys and he came up with a toy that he wanted to make."
	Ellie: "That Lonnie Johnson made cool inventions. He used parts from an old juke box to make robot named Linex and he didn't tell his sister this, but he used her tape recorder to use it as eyes. Mischievous but clever!"
	Makayla: "That he accidentally made the water squirt, I mean the Super Soaker." Interviewer: "What else do you remember about this text?" Makayla: "That when he made the Super Soaker, he was working on a heating and cooling thing and then when he sprayed it at his curtain…in the bathroom, the curtain went flying all around."
Students recalled parts of the engineering design process illustrated in the text	Carter: "…when he made his daughter test it out and then other kids in the neighborhood tried testing it out and then he made it better when he got older." (testing and improving design solutions)
	Raven: "He brought the Super Soaker to kids and then he let them try it out and then they loved to play with it." (seeking feedback about design solutions)
	Nick: "…he (*Lonnie Johnson*) made a Super Soaker and to test it he had his kids test it and other neighborhood kids test it." (testing design solutions)

When asked about how reading and learning about Lonnie Johnson helped students understand more about what engineers do, students reported that the text (a) provided an example of how engineers design solutions by describing how Lonnie Johnson designed the Super Soaker (10 students), (b) described Lonnie's motivations to become an engineer (1 student), and (c) provided information that students could use to design their own solutions (2 students). Two additional students reported that they either did not know how the text was helpful or were unsure how to answer the question. Data from a teacher interview about the Lonnie Johnson texts provide additional evidence that the texts helped students build knowledge about how engineers design solutions: "…it (*the text*) definitely helped the engineering process in terms of, you know…there was a question, there was something to ask, he (*Lonnie Johnson*) had to come up with a plan, he wanted to create something." Table 5.9, below, provides illustrative excerpts from students' interview responses.

Table 5.9

How the Text Helped Students Understand What Engineers Do

Findings	Examples from Interview Transcripts
The text provided an example of how engineers design solutions	Raven: "It helped me understand more about what engineers do by like when it told us like…how they invent things and like how…if they have patents like no one else can take what they're doing and copy off of them."
	Owen: "That they usually improve stuff and they make, they never stop making stuff."
	Aiden: "Well, it helped a lot because for one, it helped a lot because it actually gave us a lot of data on what happened in 1991 when someone, Lonnie George Johnson, created the Super Soaker."
The text described Lonnie's motivations to become an engineer	Brandon: "Because he wanted to be, when he was a kid, he wanted to be a toy builder because he was playing with toys when he was a kid because he wanted to build toys."
The text provided information students could use to design solutions	Malik: "It helped me learn to help people and build things to help them."
	Ellie: "He is an engineer and he gave us some, I mean he's not really talking to us, but he gave us some pointers on what we could do or what we could build." Interviewer: "Like what?" Ellie: "Like that back when he was a child they didn't get very wet with the toys that they had, so he did something about it. He didn't just sit there and…get hot. He just wanted to…get involved and do something about it."

These interviews revealed what the students found salient about the ideas in the text, and what students reported was helpful to their learning about the work of engineers. While student interviews do not reveal all that students know or learned in this context, they do provide a helpful source for extending enactment findings regarding how the Lonnie Johnson texts and tasks supported students' science and literacy learning in the PBL unit. As mentioned previously, field notes and transcripts from enactment revealed that some students did not "enter the discussion" at all during the Lonnie Johnson lesson. However, these students interview responses suggest that they were, nonetheless, making meaning and meaningful connections along with their classmates who were more active in class discussions.

Conclusion

While we cannot isolate the features of the text from its enactment, there did appear to be certain affordances associated with both the design of the text and its placement in the curriculum, based on data analyzed from the enactment and student interviews. The design of the text and the teacher's enactment supported students to leverage prior knowledge, make connections to firsthand experiences, learn about and motivate the use of scientific and engineering practices, deepen and use vocabulary and conceptual knowledge, and to make connections and build knowledge across multiple, multimodal texts, as they read, viewed, and discussed the Lonnie Johnson text set. These findings are useful to informing the design – and use of – paired texts and tasks, in the context of project-based science, that support teachers to: teach and engage students in using challenging scientific and engineering ideas and practices, and engage students in instruction that places scientific language and literacy in interplay.

PART II: The Balloon Rocket Story and Investigation

In the second part of this chapter, I focus on the design and use of a researcher-designed text, *The Balloon Rocket Story* (Appendix E). The text focuses on disciplinary core ideas of force, motion, and engineering design, and was supported by a researcher-designed interactive reading guide (Appendix F). First, I describe the design features of the text and task, and then describe the enactment. To address my research questions, I (a) describe the ways in which the design and enactment of *The Balloon Rocket Story*, teacher resources, and investigation supported students' science and literacy learning; and (b) identify modifications to the design of the text and tasks that might enhance students' science and literacy learning, in the context of project-based science instruction.

Design of the Text: The Balloon Rocket Story

The Balloon Rocket story is a hybrid genre of text that has both narrative and expository elements. It was designed to: (a) introduce students to disciplinary core ideas (e.g., the role of friction in motion) useful to sense-making; (b) provide information that connected to and build upon students' first-hand observations, experiences, and knowledge; (c) provide a context for, guide, and motivate first-hand investigations of the role of friction in motion, and (d) demonstrate scientific practices, such as planning and conducting fair tests and observing phenomena closely.

In Part I of *The Balloon Rocket Story*, two children (Jamal and Maria), are trying to build their own balloon rocket toy, but cannot make it work. This sets the context for students to plan and conduct their own investigation using the balloon rocket toy in order to advise the characters in the story about how they should proceed in order to solve the problem with their balloon rocket toy. Then, in Part II of *The Balloon Rocket Story*, Jamal and Maria talk with Aunt Sophie, who is an engineer, about how they could investigate their balloon rocket toy to figure out why it is not working. Part II of *The Balloon Rocket Story* emphasizes the importance of conducting fair tests in scientific investigations and introduces the idea of friction.

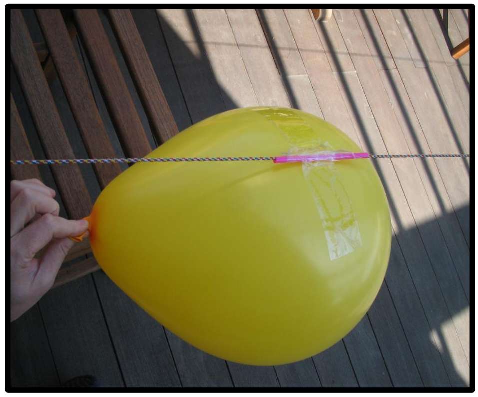


Figure 5.1. Photograph of Balloon Rocket by Dean Johnson/Flickr: https://creativecommons.org/licenses/by-nc/2.0/. This figure illustrates the balloon rocket set up used in the classroom.

The interactive reading guide that accompanied the text was designed to support the teacher's enactment and to engage students in reading, interpreting, and discussing the ideas in *The Balloon Rocket Story*. Specifically, the viewing guide was designed to include a variety of (a) discussion questions and prompts; (b) opportunities to engage students in first-hand observations, demonstrations, and investigations; and (c) opportunities to make connections to students' prior knowledge and experiences.

Overview of Enactment

Prior to reading the text, *The Balloon Rocket Story,* the teacher introduced the balloon rocket setup in class and invited students to make initial observations of the parts of the toy. *The Balloon Rocket Story* is written in two parts. Part I of the Balloon Rocket Story provided an occasion for the students to make observations of the variety of materials from which the characters in the story could select to: build their balloon rocket toy, introduce the characters' (Jamal and Maria's) initial attempts to get their balloon rocket to work using the set of materials, and illustrate the characters' multiple failed attempts.

Next, the students were invited to speculate why the balloon rocket in the story would not move, identify and ask questions about the parts of the balloon rocket toy and what could "go wrong" with the parts, discuss as a class how to design a fair test to investigate their ideas, and then plan and conduct their own balloon rocket investigation to determine why the balloon rocket in the story did not move. After collaboratively planning and conducting their first-hand investigation in class, students made an evidence-based claim prior to reading Part II of the Balloon Rocket story, which introduced the ideas related to thinking of the balloon rocket in terms of a system, the role of friction in motion, conducting fair tests and controlling variables.

Having first-hand experience with planning and conducting a class investigation prior to reading Part II of the text, positioned the students as “more knowledgeable others” (Litowitz, 1993) as they read. Finally, after completing the reading, students revisited and revised their evidence-based claims to incorporate the ideas seeded in the text related to how friction affects the motion of the balloon rocket in their investigation. The enactment timeline (Table 5.10) illustrates the flow of activities across multiple days of instruction.

Table 5.10

Balloon Rocket Text and Investigation Enactment Timeline

Lesson	Day	Lesson Activities
Lesson 3.1: How does friction impact how toys move?	Day 1 43 mins.	• Students observed balloon rocket toy in classroom, make predictions about how it works, and make predictions about what could “go wrong” to prevent the balloon rocket from moving • Teacher engaged students in interactive read-aloud of Balloon Rocket Story Part I • Teacher demonstrated the balloon rocket context described in the story; students make observations • Class discussed how to design a fair test
	Day 2 65 mins.	• Teacher-led collaborative planning and conducting of balloon rocket investigation, using fair tests • Recorded observations and measurements • Discussed results
	Day 3 35 mins.	• Reviewed investigation question • Revisited and analyze data • Teacher and students worked together to make evidence-based class claim
Lesson 3.2: Why doesn’t the toy move?	Day 4 71 mins.	• Revisited first-hand investigation and evidence-based claims • Class determined how they would advise Jamal and Maria on how to get their balloon rocket to move

		• Teacher engaged students in interactive read-aloud of Balloon Rocket Story Part II • Revisited and revised evidence-based claims from first-hand investigation

Testing Conjectures

In analyzing and reporting data specific to the design and enactment of the *Balloon Rocket Story* and investigation task, I foreground the following features of the designed MLs learning environment (i.e., *embodiment*): (a) the designed tools and materials, including teacher supports (i.e., lesson plans, interactive reading guide) and multimodal literacy resources (i.e., text); and (b) the task structure. The *mediating processes* outlined in my conjecture map served as analytic lenses, guiding my analyses of enactment data and interviews. For instance, to understand whether and how *mediating processes* produced *desired outcomes* within this set of lessons, I drew on enactment transcript and interview data in order to closely analyze the ways in which these *mediating processes* emerged and unfolded in the classroom.

The close analysis of the transcribed video of lesson enactment allowed me to analyze the ways in which the designed tools and materials (e.g., teacher supports, literacy resources) and task structure produced observable interactions: (a) using tools of reading, writing, viewing, and discussing for meaningful purposes, (b) using scientific ideas and practices, (c) building on prior knowledge and funds of knowledge, and (d) the teacher's instructional moves. Analyzing observable interactions revealed within transcript data, in combination with interview data, allowed me to examine whether and how these *mediating processes* led to *desired outcomes*, including: (a) making sense of and synthesizing multimodal texts and (b) using science ideas and practices to make sense of an explain phenomena.

Findings

Findings from enactment. In this section, I draw on my analyses of the text enactment data (lesson plans, field notes, and transcribed video recordings) and interview data to respond to my research questions: (1) How did *The Balloon Rocket Story* and investigation support third-graders' science and literacy learning? (2) What modifications to the design of the Balloon Rocket text and investigation might better support third-graders' science and literacy learning, in the context of project-based science instruction?

I found that the design of the text and tasks, and the teacher's enactment of *The Balloon Rocket Story* synergistically supported third-graders' science and literacy learning. In Table 5.11, I describe features of the text design, features of the reading guide and lesson plan design, and features of the teacher's enactment for the purposes of illustrating this interplay. Following the table, I describe how the features included in each row synergistically supported students' science and literacy learning and provide illustrative examples from enactment data.

Table 5.11

Overlapping Supports in Design of Text, Curriculum Tools, and Enactment

Balloon Rocket Text Design	Reading Guide & Lesson Design	Teacher Enactment
Finding 1: Building background knowledge and setting a purpose for reading		
The text was written to include a moving toy that used materials that students could observe and investigate in the classroom firsthand.	The lesson plan identified opportunities for the teacher to engage students in first-hand experiences to build background knowledge prior to reading, and to set a purpose for reading.	The teacher engaged students in first-hand experiences to build background knowledge prior to reading, and to set a purpose for reading.
Finding 2: Tacking between ideas in the text and first-hand experiences		
The text was written to include supportive questions that bridged the ideas in the text with students' classroom investigation (e.g., *What could you do to help Maria and Jamal figure out why their balloon did not move?*)	The reading guide identified opportunities for the teacher to make connections between the text and first-hand experiences.	The teacher supported students to tack between ideas in the text and first-hand experiences.
Finding 3: Engaging in scientific and engineering practices		
The text was written to motivate students' use of scientific practices (e.g., making predictions and observations, asking testable questions, and planning and conducting investigations).	The reading guide identified opportunities to engage students in scientific practices.	The teacher used the text and first-hand experiences to engage students in scientific practices.
Finding 4: Introducing vocabulary and encouraging precise uses of language		
The text was written to introduce and/or revisit science vocabulary (e.g., friction, force, variable, and system).	The reading guide identified opportunities for the teacher to emphasize and clarify science vocabulary.	The teacher used the text to emphasize and clarify vocabulary and encouraged students to use

		precise language when communicating ideas.
Finding 5: Modeling and using reading strategies		
	The reading guide identified opportunities for the teacher to engage students in reading strategies, such as making predictions.	The teacher modeled and encouraged students to use reading strategies, such as visualizing and making predictions.
Finding 6: Introducing and describing core science ideas		
The text was written to introduce and clarify core science ideas (e.g., friction).	The reading guide identified ways to support students' sense making around core science ideas.	The teacher used the text to introduce and clarify core science ideas.
Finding 7: Providing opportunities for students to make connections to prior knowledge and experiences		
The text was written to connect to students' experiences within the larger unit of instruction.	The reading guide identified opportunities for the teacher to make connections to students' prior knowledge and experiences.	The teacher provided opportunities for students to make connections to prior knowledge or experiences.

As suggested in the lesson plan, the teacher engaged students in first-hand experiences to build background knowledge prior to reading, and to set a purpose for reading. On the first day of instruction, the teacher demonstrated the balloon rocket set up in the classroom, asked students to identify the parts of the balloon rocket, and previewed the problem introduced in the text. This gave students first-hand experience with the balloon rocket, and an opportunity to: observe and analyze the parts of the toy and begin thinking about what might "go wrong" to prevent the balloon rocket from working, bolstering students' background knowledge prior to reading. Illustrative examples are provided in Table 5.12, below.

Table 5.12

Building Background Knowledge Through First-Hand Experiences

Transcript Excerpt	Description
Teacher: So, we are going to read a story about a couple of kids that are trying out an experiment…So, there are some pieces that they're using, all right, to try to get this balloon rocket to work…It's kind of like a system. What are the parts of this system that we're using, Ellie? **Ellie:** Twine! **Teacher:** Okay, we're using twine. What else are we using, Keyanta? **Keyanta:** A balloon. **Teacher:** A balloon. **Ellie:** A yellow, medium round balloon. (Day 1)	In this excerpt, the teacher previewed the text, introduced the balloon rocket as a system, and asked students to observe the balloon rocket setup to identify the parts of the toy prior to reading. In the excerpt provided, students identified the parts of the balloon rocket system in the class. Following the excerpt, other students continued to identify the parts of the system they observed.
Teacher: These kids can't seem to get their balloon	In this excerpt, the teacher previewed the problem

rocket to work, alright? So those [*the balloon rocket set up in the classroom*] are the parts of this system, all of these things working together. Let's see what they did. Alright, so now you can go ahead and go to Balloon Rocket Story Part I. (Day 1)	introduced in the text, connected the problem to the balloon rocket toy students just observed in the classroom, and launched Part I of the text.

Using the text itself and suggested prompts in the reading guide, the teacher supported students to tack between ideas in the text and first-hand experiences. Across the four days of enactment, the teacher supported students to tack back and forth between the ideas in the text and students' first-hand experiences. This ranged from supporting students to: (a) compare their first-hand experiences to the experiences of the characters in the text, (b) use ideas in the text to create the context for and to motivate the design and conduct of a first-hand investigation, (c) use first-hand data to make predictions about what "went wrong" with the balloon rocket in the story, and (d) use ideas from the text to revisit and revise evidence-based claims to explain findings from students' first-hand investigation of the balloon rocket.

The continuous tacking between the ideas in the text and students' first-hand experiences across the four days of enactment in this context, echoes the findings of Palincsar and Magnusson's (2001) research on the interplay of first-hand and second-hand investigations. In their work, Palincsar and Magnusson (2001) found that the teacher engaged in a continuous process of tacking between students' experiences and the ideas in the text in order to make knowledge claims. We argue that making the connections between text and experience salient across lesson activities kept student thinking in the foreground, supported but not usurped by the ideas in the text. I provide excerpts from transcripts in Table 5.13, below.

Table 5.13

Tacking Between Ideas in the Text and First-Hand Experiences

Transcript Excerpt	Description
Teacher: You guys didn't think it [*the balloon rocket set up in the classroom*] went very far. So, let's look at these. Let's look at the materials we have [*Teacher scrolls up the SMART Board screen to allow students to review the materials that Maria and Jamal had to choose from to build the balloon rocket in the story*]. Okay, what is it that we want to investigate? [Student 3]? **Aiden:** If we move the toy with some of these things would it make it better or worse? **Teacher:** So, that's really broad. So, let's narrow it down. What's one thing that we're wondering might change how fast the balloon rocket goes? (Day 1)	In this excerpt, the teacher referenced students' experiences with the balloon rocket set up in the classroom, then directed students to review the materials that were available to the characters in the story. The teacher then used this connection (students' experience with the balloon rocket and the materials described in the text) to ask students what, about the balloon rocket, they should investigate in the classroom. Aiden proposed an investigation question, and the teacher pressed the class to identify a specific variable that might affect the movement of the balloon rocket.
Teacher: So, Ellie's remembering something from yesterday. She's remembering...that yesterday they [*Jamal and Maria in the Balloon Rocket Story*] said that all their balloon did… **Ellie:** It just bounced up and down and this one did too! **Teacher:** It did. It did kind of bounce up and down, didn't it? (Day 2)	In this excerpt, the teacher foregrounded a connection introduced by one student, who identified that when the students observed the balloon rocket in the classroom, their observations matched those made by the characters in the text (e.g., "It just bounced up and down and this one did too!").
Teacher: [*Reading from the Balloon Rocket Story*] I saw the balloon start to move, but it just seemed to...bounce up and down. **Ellie:** Just like ours did. **Teacher:** Okay, ours did the same thing, didn't it? Absolutely. Now, we kind of already know. We conducted more experiments, right, more tests than they did… What do you think they may have done wrong? Why do you think their experiment did not happen, [*student's name*], the way that they wanted it to? Keyanta? **Keyanta:** Because there might have been that there was a knot in it, or Maria didn't tie it. **Teacher:** Okay, Maria didn't tie it. Now, think about our twine. If you had your notebooks out, you would probably remember that the twine pretty much went the same distance each time. Does anybody remember what that distance was? Show me on your fingers. About how far did the twine travel? Just about three inches, right? (Day 4)	In this excerpt, the teacher read aloud from the text, and again foregrounded a connection introduced by a student: when students observed the balloon rocket in the classroom, their observations matched the observations made by characters in the text. Then, the teacher emphasized that the class had done more tests than the characters in the story and asked the students what they thought the characters in the story might have done wrong based on their first-hand investigation. One student suggested that there might have been a knot in the twine [On Day 1 of enactment, one students began describing the rough texture of the twine as knots. As reflected in this excerpt, this idea was taken up by other members of the class in their descriptions of the texture of the twine.]. The teacher continued to support students to tack between the ideas in the text and their first-hand investigation by asking students to recall and share the data they gathered about the distance the balloon rocket traveled on the twine.
Teacher: Is there any other statement we could add [*to our evidence-based claim from the first-hand balloon rocket investigation*] based on what we read today? Is there anything else that we could add, any more evidence that makes us think that the yarn allowed it to go farther? … Makayla? **Makayla:** That there wasn't as much friction. **Teacher:** There wasn't as much	In this excerpt, the teacher revisited students' explanations from their first-hand balloon rocket investigation. The teacher asked whether students could use any of the ideas in the text to bolster their explanation of the balloon rocket phenomenon. Makayla suggested that they could add what they learned about friction to their evidence-based claim.

friction where? **Makayla:** On the string. (Day 4)	Recall that the role of friction in motion was described in the text.

The teacher used the ideas in the text and students' first-hand experiences, along with suggestions in the reading guide, to engage students in scientific practices. Across the four days of enactment, the teacher used the ideas in the text and students' first-hand experiences to engage students in scientific and engineering practices (see Table 14), including: (a) asking questions and defining problems, (b) planning and carrying out investigations, (c) using mathematics, (d) analyzing and interpreting data, and (d) constructing explanations and designing solutions. Based on these findings, I argue that the design of the *Balloon Rocket Story* and the teacher's enactment serve as one illustration of how a text can be designed and enacted to serve as "a catalyst for engaging in science practices" (NRC, 2014, p. 13). In this context, the *Balloon Rocket Story* presented a problem and seeded ideas that served as a meaningful context for students to: (a) identify possible design problems and ask testable questions about why the balloon rocket in the story was not working, (b) plan and conduct first-hand investigations to explain why the balloon rocket in the story was not working, (c) determine how to measure their data (i.e., using mathematics), (d) represent and interpret collected data regarding how far the balloon rocket traveled on each different type of string, and (e) use evidence to support an explanation and (f) appropriate science ideas introduced in the text to solve the balloon rocket design problem.

Table 5.14

Engaging in Scientific Practices

Transcript Excerpt	Description
Teacher: What do you think we could do...to help Jamal and Maria with their experiment? ...What do you think we could do? …**Keyanta:** Tell them to use the	In this excerpt, the teacher asked students what they could do to help the characters in the story with their experiment by planning their own first-hand

thinner string because this [*the balloon rocket*] gets stuck, [*the twine*] gets very big knots. **Teacher:** Okay, has a lot of knots. So, let's think about this. If we were going to try, what did you say we should do? Try what? **Keyanta:** We should try a thinner string and then it can go [*all the way up to the top*], and then it doesn't stop. **Teacher:** Well, we are hoping that's what happens. So, you're thinking that if we had thinner string that it would go all the way up to the top. Okay, would we want to change anything else if we were just testing the string? [Student 5] is giving me a thumbs down. (Day 1)	investigation. One student suggested that they should test a thinner string to make the balloon rocket travel farther. The teacher then asked the class if they should change any variables in addition to the string. Following Student 5's response, the class continued to talk about how they could design a fair test.
Teacher: What are we going to test? **Keyanta:** We're going to test the twine, the thread, or the yarn. **Teacher:** Okay, so let's say we're going to test the twine first… What are we going to look for to see if there was a change in the movement? **Student:** Measurement! Measurements. **Teacher:** Measurements. **Student:** From a yardstick. **Teacher:** Okay, we could use a yardstick. **Student:** How long it goes. (Day 2)	In this excerpt, the teacher asked students to identify what could serve as evidence in their first-hand investigation. The teacher pressed students to identify how they could make observations and/or measurements to produce data. In this excerpt, a student suggested that the class could use a yardstick to measure the distance the balloon rocket travelled. Following this excerpt, the class continued to discuss how to conduct a fair test and measure each trial.
Teacher: Do we notice anything about our data? Do we notice anything about the data we collected? If you're not looking at the data, you're not going to be able to make any noticings. But if you look at the data, you might be able to notice something about it. Ellie, is there anything that you notice about the data we collected? **Ellie:** For the twine, it didn't go that far. It mostly stayed the same. (Day 3)	In this excerpt, the teacher engaged students in analyzing and interpreting their data to make sense of the balloon rocket phenomenon. In the excerpt provided, one student begins by sharing something she noticed about the investigation data. Following this exchange, the teacher collected, discussed with the class, and recorded noticings from six additional students.

The teacher used the text and suggestions in the reading guide to emphasize and clarify vocabulary, and also encouraged students to use precise language when communicating ideas. There was an emphasis on language across the four days of enactment. Particularly on Days 1 and 4, when the teacher and students read and discussed the text, the teacher used the text to emphasize and clarify vocabulary (e.g., thickness, texture, system, engineer, friction). In addition to this focus on vocabulary, the teacher also consistently encouraged students to use precise language when communicating their ideas across the four days of enactment (reference Table 5.15)

Table 5.15

Clarifying Vocabulary and Encouraging Students to Use Precise Language

Transcript Excerpt	Description
Aiden: They could have put too much pressure in it and it could have flew. **Teacher:** Okay, so instead of using words like *it*, because we've got a straw, a balloon, and we've got this twine, so when you say *it*, I'm not really sure what you're talking about. **Aiden:** They could put too much pressure inside the balloon and when they let go, the balloon could fly off the tape or the straw. (Day 1)	In this excerpt, the teacher explained that when students' use words like *it* when they are making an observation or describing how different parts of the balloon rocket system work together, it is important to use more precise language. The student then revised his prediction to include more precise language (i.e., the balloon instead of it).
Teacher: Okay, so what does that mean, the different thickness? ...I'm asking about thicknesses first. What do you notice about the thicknesses, Aiden? **Aiden:** Two of them have very little, two of them are very thick and one isn't, doesn't really look that thick. **Teacher:** Okay, so they're different thicknesses, right? So, different widths. Alright, what about textures? What does that mean? That was one of our vocabulary words not that long ago. What does that mean? **Lucas:** Textures means that like the kind of feeling it has, like those two, the red and the rainbow-colored ones. **Teacher:** These two? [*The teacher walks up to the SMARTboard and points to the pictures of the yarn and the string.]* **Lucas:** Yeah. Those ones are soft. (Day 1)	In this excerpt, the teacher asked students to make observations using photographs embedded in the *Balloon Rocket Story*. The teacher asked students to focus specifically on the thicknesses and textures of the different types of string and to describe what they noticed.
Teacher: How could we change what? **Julia:** The balloon rocket. **Teacher:** Hmm, I think we can get a little bit more specific than that. Aiden? **Aiden:** If we change the string, how would it affect the toy? (Day 2)	In this excerpt, the teacher and students were working to collaboratively develop an investigation question to guide their first-hand balloon rocket investigation. The teacher pressed students to be more specific within their question.
Teacher: Alright, what's evidence? What's evidence? [Student 8], what's evidence? **Emmy:** It's like proof. **Teacher:** ...What proof do we have? **Teacher:** So, on our paper, we could write, "The balloon rocket traveled the farthest distance when we used yarn… And then, what do we need to have to support that? **Multiple students:** Evidence. Proof. **Teacher:** …Okay, we have to have evidence. How do we know? (Day 3)	In these excerpts, the teacher asked students to describe the meaning of evidence and then proposed a few additional ways to think and talk about evidence as "proof" or "support" for a claim.
Teacher: Instead of saying *went*, what could we say? What's a stronger verb? **Multiple students:** Flew. Traveled. (Day 3)	In this excerpt, the teacher and students were collaboratively writing a class claim. When drafting the claim, the teacher asked if any students could think of a stronger verb to describe what happened in the balloon rocket investigation.
Teacher: What is a system? She's [*Aunt Sophie in the Balloon Rocket Story*] talking about what things are	In this excerpt, as the teacher read aloud from the *Balloon Rocket Story*, she paused to clarify the

touching one another in your system. What do we know about systems? [*Students share multiple examples of systems including the solar system, a conveyor belt, and a treadmill.*] **Teacher:** But what do they all do? **Ellie:** They work together. **Teacher:** They all work together, right? A system is something that's working together. So, stop and think about everything. What are the parts of their system? Raise your hand and remind us what are the parts of their system? [Student 9], what's one? **Cameron:** A medium balloon rocket. (Day 4)	meaning of the word, *system.* Before moving on, she asked students to share what they knew about systems and to review the parts of the system in the balloon rocket toy.
Teacher: There is friction between the twine and the straw when the balloon rocket moves and for scientists and engineers, friction is a force [*reading from the text*]. Friction is a what? **Multiple students:** Force. **Teacher:** Friction is a what? **Multiple students:** Force. **Teacher:** Friction is a what? **Multiple students:** Force. **Kaylee:** A force is a push or a pull. **Teacher:** [*Reading*] It is a force that stops or changes the direction or motion. **Teacher:** ...So, let me ask you this. Let me ask you what Maria just asked. How is twine a force...because force is a push or a pull? **Ellie:** Because it's friction. **Lucas:** It's pulling the balloon rocket back. **Teacher:** What do you mean it's pulling it back? **Lucas:** Yeah, it's pushing it back, I mean, because the chunks, knots, or the rough surface is making it so it's pushing onto it, but it's not going to let it because it's pushing on too. **Teacher:** So, the twine is pushing back against it you're saying? **Lucas:** Yeah. (Day 4)	In this excerpt, as the teacher read aloud from the *Balloon Rocket Story*, she paused to emphasize and to clarify the meaning of the word, *friction.* Before moving on, she posed to the class a question that one of the characters, Maria, had asked in the story.

The teacher modeled and encouraged students to use reading strategies, including but not limited to those suggested in the teaching guide, such as visualizing and making predictions. While reading and discussing the *Balloon Rocket Story* on Days 1 and 4 of enactment, the teacher modeled and engaged students in using reading strategies (reference Table 5.16, for illustrative examples). While reading Part 1 of the *Balloon Rocket Story*, the teacher elicited students' predictions about why the balloon rocket in the story might not be working. She also modeled and engaged students in visualizing events and scenes within the text, particularly with respect to picturing the parts of the balloon rocket system and how they work together. We found that the teacher also emphasized the reading strategies of making predictions and visualizing on Day 4, while reading Part II of the *Balloon Rocket Story*.

Table 5.16

Modeling and Encouraging Students' Use of Reading Strategies

Transcript Excerpt	Description
Teacher: "They can't seem to get theirs to work. This is what they're using and these kids can't seem to get it to work. **Ellie:** Because they're using twine! **Teacher:** Okay, you think because they're using twine…Keyanta? **Keyanta:** That maybe the balloon's too small… [*The teacher calls on several more students to make predictions about what might "go wrong" with the balloon in the Balloon rocket story that could prevent the balloon rocket from working. As students share their ideas, the teacher records them on chart paper.*] **Teacher:** Let's see what they did. (Day 1)	In this excerpt, the teacher previewed the text by introducing the idea that the children in the *Balloon Rocket Story* cannot get their balloon rocket to work and then fielded predictions from the students about what might go wrong with different parts of the balloon rocket in the story to prevent it from working.
Teacher: Maria tied the twine to a tree, pulling it as tightly as she could [*reading from the text*]. So, I'm picturing in my mind they kind of made this, right? (*The teacher holds up the balloon rocket set up in the classroom for students to observe.*) And she didn't just let it hand there like this. It said she did what? **Multiple students:** Pulled it tightly. **Teacher:** So, she pulled it really tight, right? (Day 1)	In this excerpt, the teacher read from the text and then described for students what she was picturing in her mind as she read. The teacher followed her description of how she visualized the ideas in the text, by demonstrating for students what she pictured using the balloon rocket set up in the classroom.

The teacher used the text itself and suggestions in the teaching guide to introduce and clarify core science ideas. When the teacher read aloud Part II of the *Balloon Rocket Story* with the class, she used the text to introduce and clarify core science ideas such as the role of friction in motion, thinking about the balloon rocket toy as a system, and changing only one variable at a time to conduct a fair test. While the teacher introduced the idea of thinking about the balloon rocket toy as a system on Day 1 of enactment when she asked students to identify the parts of the balloon rocket toy, she also used the ideas in the text on Day 4 to support students to revisit and emphasize the idea of a system. Similarly, the teacher introduced the idea of designing and conducting a fair test on Day 1, after the class read Part I of the *Balloon Rocket Story*. Introducing these ideas was necessary at this time in order for the teacher to support the class in collaboratively planning and conducting an investigation of the balloon rocket system using fair tests. Then, on Day 4, the teacher used the ideas in Part II of the *Balloon Rocket Story* to revisit and clarify the role of fair tests in investigations as the class read and discussed the story.

Finally, on Day 4 of enactment, the teacher used the text to introduce the idea of friction and the role of friction in motion. The teacher introduced the term, *friction*, during the read aloud of the text, then paused the read aloud to pose a question, asked by one of the characters in the text, back to the class: "**Maria:** 'Yeah, how can the twine be a force?'" After introducing, discussing, and clarifying the meaning of friction using the text, the teacher guided students to draw from the ideas in the text when they revisited and revised the explanations they wrote about the class' firsthand balloon rocket investigation. Table 5.17, below, provides examples from enactment.

Table 5.17

Introducing and Clarifying Core Science Ideas

Transcript Excerpt	Description
Teacher: You have already thought about a lot of important things...things that a scientist or engineer would think about. They would also think about what the...balloon rocket is in contact with. What things are touching one another...in your system [*reading from the text*]? What is a system? She's [*Aunt Sophie in the Balloon Rocket Story*] talking about what things are touching one another in your system. What do we know about systems? (Day 4)	In this excerpt, the teacher read from the part of the text that introduced the idea of thinking about the balloon rocket as a *system*. Although the teacher introduced the term, *system*, as students made observations of the different parts of the system on Day 1 of enactment, the teacher paused here as well to discuss and clarify what students knew about *systems*.
Teacher: There is friction between the twine and the straw when the balloon rocket moves and for scientists and engineers, friction is a force [*reading from the text*]. Friction is a what? ...So, let me ask you this. Let me ask you what Maria just asked. How is twine a force...because force is a push or a pull? (Day 4)	In this excerpt, the teacher read from the part of the text that introduced the idea of *friction*. The teacher paused to talk with students about the *friction* and to discuss how these ideas related to other science ideas students were learning about in the unit (e.g., force).

The teacher provided opportunities for students to make connections to prior knowledge or experiences, including but not limited to the suggestions in the reading guide. A final affordance of the enactment was that the teacher embedded opportunities for students to make connections to prior knowledge or experiences. These opportunities ranged from supporting students to make connections to other tasks from the same unit of instruction to supporting students to make connections among the ideas in the text and other daily experiences (see Table 5.18). This supported students to, not only make sense of the ideas in the text, but to build on their prior knowledge and experiences as they encountered new ideas in the text.

Table 5.18

Providing Opportunities to Make Connections to Prior Knowledge and Experiences

Transcript Excerpt	Description
Teacher: Two third graders, Jamal and Maria, who have been reading about how to make toys in their classroom [*reading from the text*] ... Raise your hand if you can relate to anything we've read so far. Kaylee, what can you relate to? **Kaylee:** That we've been working with the super soakers and we've been making our own toys and trying to improve. **Teacher:** Trying to improve them. What kinds of toys are we talking about improving? Kayla? **Kayla:** The cart or the car. **Teacher:** What kinds of toys are those? **Kayla:** Moving toys. (Day 1)	In this excerpt, the teacher read aloud the first sentence of the *Balloon Rocket Story*, then engaged students in identifying and sharing what they could relate to at this point in the text. The teacher encouraged the students to make connections to their prior experiences learning about toys in the classroom during the unit and designing and improving their own moving toys.
Teacher: ...to reduce the friction. You're using it right now… Without these it would be a lot louder in here and it would not be as easy for you to get in your seat… What is it that we use here to reduce the friction of the chair? **Student:** The tennis balls! **Teacher:** Okay, I'm going to stand about the same spot and I'm going to push this chair. **Student:** It was tennis balls! **Teacher:** Which one went farther? **Students:** The tennis balls. **Teacher:** Tennis balls. Okay, so just kind of pay attention to where you see reduced friction of how you can reduce friction everyday - everyday uses. (Day 4)	In this excerpt, after reading the *Balloon Rocket Story* and engaging students in a friction demonstration, the teacher supported students to connect these ideas to items they use in the classroom on a daily basis that affects the amount of friction between objects.

Constraints of the text and task revealed through enactment. In addition to the ways in which the text and task supported students' science and literacy learning, my analyses also revealed limitations. A potential limitation is that the students did not have the opportunity to construct the meaning of the text without the advantage of the firsthand experience. This is relevant to our work because the MLs team is committed to providing students the opportunity – and support – to construct mental models of text by interpreting and synthesizing the ideas within the text. In other words, there are occasions when students must interpret text without the benefit of first-hand experience. This text-task pairing did not provide such an opportunity.

A second limitation is that, while many students in the class had multiple opportunities to participate directly in the collaborative teacher-led balloon rocket investigation and to share their ideas as they planned and conducted the investigation and read and discussed the *Balloon Rocket Story*, this was not true of all students. Although the teacher capitalized on opportunities to sample many students' ideas as they discussed the text and firsthand experiences, this sampling does not guarantee that every student in the class was "on the same page" with respect to making sense of the new ideas presented and building on their prior experiences productively. Because of this limitation, we began to design opportunities for students to make digital written entries in response to many of the texts included in the curriculum, described in Part I of this chapter.

A final limitation, or challenge, inherent within this design work is the complexity of making decisions about how to distribute time and attention within and across lessons. In other words, the design team continues to grapple with how to balance activities that engage students in firsthand exploration of phenomena with opportunities for students to read and build meaning with text. Finding this balance, and strategic ways to integrate first-hand and text-based experiences such that these experiences work synergistically to engage students in scientific practices and support students to make sense of scientific phenomena continues to be a MLs aim.

Findings from student interviews. In this section, I describe findings from interviews conducted with focal students that provided additional insight about students' science and literacy learning in the context of The Balloon Rocket Story and investigation. The interview protocol consisted of a subset of questions from a larger interview protocol, which contained questions about all texts included in the unit of instruction. Questions specific to the *Balloon Rocket Story* and investigation included: (1) What do you remember about this text? (2) How was this text helpful? (3) Is there anything that we could do to make this text more helpful to your learning? (4) How did you use the ideas in this story to help you with your toy car friction investigation (that students planned and conducted immediately following The Balloon Rocket Story and investigation)?

The interview was conducted a month after the students worked with the text and was designed to explore what students recalled about the text, students' perspectives on the helpfulness of the text and ways the text could be improved to help them learn more, and finally, how the students reported using the ideas introduced in *The Balloon Rocket Story* and investigation to plan and conduct their own investigation of the role of friction in motion using toy cars. I first report how the students responded to the open-ended question specific to what they recalled about reading the balloon rocket story.

All sixteen students reported that they remembered reading the text. Fifteen of the sixteen students referenced the context introduced in the story and the balloon rocket phenomenon. Fourteen of the sixteen students also referred to one or more parts of the balloon rocket system (e.g., track, balloons, tape, etc.) when asked what they recalled about the text. Ten students offered a partial explanation for why the balloon rocket did not work and/or suggested ways to fix the balloon rocket in the story. None of the students provided a complete explanation regarding the failure of the balloon rocket to work. To qualify as a complete explanation, the student would have had to identify the role that friction, as a force that slows or stops motion, was playing, although they would not have to use the word, "friction." This does not imply that the students were not aware of the role of friction in motion; statements made in later parts of the interview reveal that a number of the students were, in fact, thinking about how friction affects a toy's motion (see Table 5.19, below). Finally, three students recalled the thought experiment that Aunt Sophie introduced in the text.

Table 5.19

Students' Recall of the Balloon Rocket Story

Findings	Examples from Interview Transcripts
Students recalled the phenomenon	Jenna: "...they tied the rope, put a straw on, and blow up a balloon and tape it on, and then it flew up."
	Leon: "I remember when the two third graders built a balloon rocket and when they first tried it out...it didn't work out so when Aunt Sophie came they...she asks them something about how they built the balloon rocket."
	Malik: "I remember the little kids...had built the thing but when...one of the little kids blew up the balloon and it didn't work, so they didn't know what to do so they rebuilt. So, they got a bigger balloon and did it again and it worked. It kind of worked but it only spinned around in one place. It didn't go anywhere, it just spinned around...and then the third time they did not know what to do so they got different things to do a different straw, and different straws and balloons."
Students recalled a partial explanation of the balloon rocket phenomenon	Carter: "...they used twine at first and they tied it to a tree and they tried making it work but it kept on getting caught on the twine so they switched it to string and then they tried with the string and it went all…it went like almost up and it hit like…like twelve inches down like a foot and umm then they used hmm…Yarn and then they used yarn and that went the farthest of all of them, but it kept on messing up with the balloon."
	Ellie: "...Someone named…Jamal and Maria…yeah. Jamal and Maria, they were trying to make a balloon rocket but it didn't work…they because of the friction on the twine."
	Owen: "Yeah. That they umm…that they tried…they tried for the first test they tried twine, thin yellow straw. If it was thin it would get caught on the knots easily. ...Umm…they umm…they umm…their aunt came and like demonstrated how, with the box and she said if it would be easier to move the box on ice for umm…instead of concrete. It's like the umm…balloon rocket, it can't, it would be easier to move with string than twine...'Cause it's smaller and they used thin yellow straws."
Students recalled the thought	Owen: "...their aunt came and like demonstrated how, with the box and she said if it would be easier to move the box on ice...instead of concrete. It's like the balloon rocket. It can't, it would be easier to move with string than twine."

experiment	Julia: “The granny…they had a box and I don’t remember but they had a box and she said she would slide it on ice to make it fast. Interviewer: “And how was that going to help?” Julia: “Umm…to get the box on there and it's really slippery…”
	Aiden: “...and Aunt Sophie described thinking of a box with - a heavy box - and pushing it on concrete and the difference between pushing it on concrete and pushing it on ice. Ice, it would probably keep going, depending on how hard you pushed it ‘cause there’s literally no friction on ice at all…”

When asked about how conducting the balloon rocket investigation helped students with their toy car investigation, six students thought analogously about the three surfaces they investigated in the toy car investigation and the characteristics of the materials used in the balloon rocket investigation. Five additional students described how the *Balloon Rocket Story* was related to their toy car investigation, but without making a comparison between the investigative conditions (Table 5.20).

Table 5.20

How the Balloon Rocket Story Helped Students with Toy Car Investigation

Findings	Examples from Interview Transcripts
Students described the conditions in the balloon rocket investigation as analogous to the conditions in the toy car investigation	Raven: “I used this to help me by like thinking of the different types of umm textures of the string and umm…and umm the twine might have more friction so I think of that being like the carpet or the towel.”
	Nick: “...the twine was like the carpet, and the string was like the towel, and the yarn was like the tile. They all had little… They all had some kind of friction in it. The twine and the carpet were similar because they were the ones that had the most friction.”
	Makayla: “I referenced like the twine as the carpet, and then the yarn as the towel, and the string as the tile...Because the twine has friction like the carpet – more friction.” Interviewer: “And what does that do?” Makayla: “Makes something that you’re trying to move go slower.”
Students drew on the relationship between the two investigative contexts, but without making a comparison	Ellie: “...the friction in the twine made it stop so if we know there’s friction on here then there’s probably going to be friction on the surface that the cars...that we’re testing on.”
	Carter: “...friction slows it down and if there’s less friction it goes farther, like on the yarn, there was less friction so it went farther. But if there’s greater friction, like on the twine it wouldn’t go that far…” Interviewer: “How is that related to the toy car investigation?” Carter: “... ‘cause when we were in the tile the car was going fast because there was less friction and the carpet wasn’t going that far, and on the towel, wasn’t going that far…”

Since the text was designed as a vehicle for introducing the students to the construct of friction, I also examined the interviews for evidence that the students made meaningful reference to friction in their responses. Most (9) students described the role of friction in the motion of toys (i.e., the balloon rocket and/or the toy cars) at some point during the interview. Two students described the role of friction in the context of the "thought experiment" in *The Balloon Rocket Story* but did not describe how friction was related to the motion of the toys the class investigated (Table 5.21).

Table 5.21

Students' Interview References to Friction

Findings	Examples from Interview Transcripts
Students described the role of friction in the motion of toys	Brandon: "Because you would blow up the balloon...and once you would let go of the balloon, it would go straight up, but there would be always a stopping point...it's because it, the friction, slows it down. The force slows it down."
	Keyanta: "I learned that we need more…less friction than more friction. We need less like the tile that we did for car…"
	Carter: "...friction slows it down and if there's less friction it goes farther, like on the yarn there was less friction so it went farther...but if there's greater friction like on the twine it wouldn't go that far."
Students described the role of friction in the context of the thought experiment	Aiden: "...and Aunt Sophie described thinking of a box with - a heavy box - and pushing it on concrete and the difference between pushing it on concrete and pushing it on ice. Ice, it would probably keep going, depending on how hard you pushed it 'cause there's literally no friction on ice at all…"
	Lucas: "So we did this to help us with the friction…the aunt told them about to imagine something and without that part you wouldn't know about the friction… So, she said that it was all…it was all just like…all like asphalt or concrete and they couldn't push it if it was asphalt they could that would be at least easier because brand new asphalt is like really smooth… but as it gets older and been there for a long time, it gets more dirty. But he imagined if ice was instead would be on there you could push it."

Recall that the text was also designed to feature the use of science and engineering practices; for example, Aunt Sophie introduced the students to (a) the idea that engineers think in terms of "systems," and (b) the role of fair tests in scientific practice. Thus, I examined the interviews for evidence that the students recalled information regarding these practices and found that two students referenced the role of fair tests in conducting an investigation (Table 5.22).

Table 5.22

Students' References to the Role of Fair Tests in Investigations

Examples from Interview Transcripts
Owen: "It wasn't a fair test, like in the story if boys and girls were racing and girls got a head start that wouldn't be a fair test [this example is taken directly from the text] ...making fair tests are better than non-fair tests."
Ellie: "They changed the twine, the thin yellow straw, and the medium round balloon but it didn't really help it… 'cause if you change all of them at once...if it works, you don't really know which one took effect… Don't change everything 'cause if it works, you don't know what will take effect, 'cause we wanted to add a lot of things so if we added them all at once we wouldn't know which one took effect."

One of the interview questions was for the purpose of asking how the text was helpful to students' learning. In response to this question, three students reported that the text was helpful because it introduced the idea of friction, six students reported that the text was helpful because it helped them learn more about building toys, and one student reported that the text was helpful because it introduced the idea of using fair tests (Table 5.23).

Table 5.23

Students' Descriptions of How the Balloon Rocket Story was Helpful

Findings	Examples from Interview Transcripts
Friction	Nick: "That the more friction there is, the less that it go…least that it goes."
	Lucas: "So we did this to help us with the friction. It helped us a lot because without this text we wouldn't know because they asked the aunt and the aunt told them about to imagine something and without that part you wouldn't know about the friction."
	Ellie: "Friction! Umm the twine it has friction on it and umm…hmm…it I don't really know how to explain it that well."
Building Toys	Raven: "It's helpful because it can teach us how to make a balloon rocket and it will teach us like maybe if you try it on the twine then maybe it won't go as far as the other two different types of string, and like if you do different types of string and like if you do different types of straws, maybe the bigger one will work because if like there is like a knot...maybe it can go over the knot...more than the small straws."
	Leon: "It helps us learn more how to build...balloon rockets."

	Malik: “How to build a balloon rocket out of balloons.”
Fair Tests	Owen: “...making fair tests are better than non-fair tests.”

Students were also invited to suggest ideas for improving the text. A total of six students offered ideas for improving the text; three suggestions focused on revising the story so that the characters built a more successful balloon rocket, while two suggestions focused on adding more details (e.g., explaining more about why the characters selected the materials they chose, show how the characters put the balloon rocket together), and one suggestion focused on changing the balloon rocket toy described in the story (Table 5.24).

Table 5.24

Students' Descriptions of How the Balloon Rocket Story was Helpful

Findings	Examples from Interview Transcripts
Making the balloon rocket in the story more successful	Carter: “They should try using like some different type of string or something, because it could make them happy and they will like celebrate when it goes like really far up.”
	Keyanta: “...instead of they don't know what to do because it kind of ends the story with a bad start and then you think, ‘Oh, we're gonna do that and we're gonna mess up.’”
	Brandon: “You could probably add...something else to it, like if you wanted to change like the string that there could be like different strings in the picture because if one string wouldn't work and you can go to another string. If that string didn't work, you go to another string, but if that string works then you have a working rocket.”
Adding information to the text	Lucas: “We could add *why* they want to use those (*materials*), so the students know in future classes...why and how they chose ‘em.”
	Ellie: “Show how they put it together.”
Making changes to the balloon rocket toy in the story	Malik: “We could add wings, like cut out paper and put it on tape and put it on the...balloon and make wings to make it look like its wings on it.”

The responses to the interview revealed that seven of the students interviewed blended the content of the text with their own first-hand experiences with the balloon rocket; this seamlessness between first- and second-hand investigations is one feature that we are striving for in the curriculum design (Table 5.25).

Table 5.25

Students Blended Ideas in the Text with Their Own First-Hand Experiences

Examples from Interview Transcripts
Carter: "They used the twine at first and they tied it to a tree and they tried making it work but it kept on getting caught on the twine ***so they switched the string and it went all...it went like almost up and it hit like...twelve inches down, like a foot, and then they used yarn and... that went the farthest of them…"*** [6]
Keyanta: "Well, we read it and then we did it. ***We showed Jamal that this works a different way***."
Nick: "***...But then it started to work when they used different materials in Part II. In part II they had...more materials and they designed it better and they used different materials than twine because twine had the little knots in it...that made it stop and then the other ones didn't so they used that.*** And they used a bigger balloon."
Raven: "***They tried to do it on different types of string and then I forgot which one went the farthest. I think it was...it was either the yarn or the thread.***"
Christian: "The kids tried to make a balloon rocket go across but it wouldn't work because thread is too thick...***They tried yarn with the smaller string and it worked.***"
Jenna: "...they tied the rope, put a straw on, and blow up a balloon and tape it on, ***and then it flew up.***"

Finally, the interview was useful for revealing points of confusion for some students (Table 5.26).

Table 5.26

Students' Interview Responses Revealed Points of Confusion

Examples from Interview Transcripts
Aiden: "...they [in reference to Jamal and Maria] were doing stuff about and they were calling friction a force and it kind of is but *I* (student supplied emphasis) would say it really wouldn't honestly be a force." Interviewer: "Okay, can you say more about that?" Aiden: "Friction and force are two completely different things!" Interviewer: "Can you tell me why you think that or what you mean?" Aiden: "Force is a push or a pull. Friction is when stuff rubs together."
Zayn: "That they go the same height, like on the carpet it goes three inches and three inches always. And the tile, it goes the same amount as the thick…the thin (*string*)."

[6] Italicized, bolded text represents ideas that the students attributed to *The Balloon Rocket Story*, but actually experienced first-hand.

These interviews revealed what the students: found salient about the ideas in the text, reported to be useful to their learning, believed would enhance their learning from the text, and remained uncertain about following the reading and investigation. In addition, the initial question, which asked the students to share what they recalled about the text, revealed the situation model (Kintsch, 2004) the students constructed from interacting with the text. While some students constructed a situation model that included only the: characters, setting, problem and solution (in other words, the features of a typical narrative), other students included in their situation model portions of the scientific explanation for what occurred in the story. This finding helps the designers give more thought to how the students' attention could be drawn to the phenomenon introduced in the text as a scientific phenomenon, rather than an everyday phenomenon (i.e., a frustrated effort to construct a toy).

I was particularly struck by the children who engaged in analogical reasoning, drawing connections between the track material (i.e., string, yarn, twine) used in the balloon rocket investigation and the features of the surfaces they investigated in the toy car investigation (i.e., tile, carpet, towel)[7]. There is long-standing interest (e.g., Goswami, 1991; Vosniadou, 1989) in the role of analogical reasoning in knowledge building, especially among children. In subsequent design cycles, I would like to exploit the opportunities for analogical reasoning so that more students have access to this way of reasoning about scientific phenomena.

In McNeill, Lizotte, Krajcik, and Marx (2006), the researchers report on the value of providing students scaffolds that will support them to engage in scientific reasoning. My interviews with students revealed ways in which *The Balloon Rocket Story* served as a scaffold to students' learning about abstract constructs, such as friction. Whereas students made claims

[7] My field notes revealed that the teacher elicited this comparison in a class discussion, two weeks prior to this interview.

and provided evidence from their first-hand investigations, one role the text played was in providing scientific reasoning in support of those claims. In fact, given the confusion apparent in some of the children's thinking about friction, in revisions to *The Balloon Rocket Story*, the design team will provide a more comprehensive description of the role of friction.

A very encouraging finding from the interview is the manner in which students were apparently integrating the reading of the text with their own first-hand investigations; I think this is ideal because the text is meant to support the students' first-hand investigations and the students' first-hand investigations are meant to support the students' reading and interpretations of text. Having text and experience in interplay is an ideal we are striving for in our development of the *Multiple Literacies in Project-based Learning* curriculum.

Conclusion

I cannot isolate the features of the text from its enactment, but there did appear to be certain affordances associated with both the design of the text and its placement in the curriculum, based on data analyzed from the enactment and student interviews. The design of the text and the teacher's enactment supported students to make intertextual connections among the narrative, their experiences with the balloon rocket phenomenon, and their design of an investigation using fair tests to determine why the balloon rocket in the text did not move. The findings are useful to informing the design – and use of – innovative texts that support teachers to: teach comprehension of science text in an inquiry mode, teach challenging scientific practices, such as designing fair tests, and engage in instruction that places scientific and language literacy in interplay.

I interviewed students about their learning experiences for evidence regarding the efficacious design of the texts and tasks (e.g., *The Balloon Rocket Story* and investigation) to support students’ science and literacy learning. The interviews provided evidence of productive ways to use text in support of learning core science ideas and engaging in scientific practices in a project-based context. The interviews, in hand with the other forms of data, enabled me to identify potential modifications to the text and the tasks to enhance effectiveness and reduce identified constraints.

Epilogue

The focus of this findings chapter centered around the design of the focal texts and the lessons in which they were enacted. However, my time in the field and analyses of field notes also revealed connections to the focal texts (*Lonnie Johnson* and the *Balloon Rocket Story*), made later in the unit of instruction, that warrant attention, and suggest implications for the design and use of literacy resources in the context of PBL.

Once introduced, the Lonnie Johnson texts served as touchstones that supported the teacher’s enactment and student learning throughout the rest of the unit. In the lessons that followed, the teacher and students drew on the shared experience of reading, viewing, and interpreting the texts and related task. In some cases, connections made to the Lonnie Johnson texts and tasks were seeded within the written curriculum; on other occasions, the third-graders spontaneously drew these connections. For example, while reading and discussing the *Balloon Rocket Story*, one student noted that the characters’ experience building toys reminded her of the Super Soaker (Unit 2, Lesson 3.1, 02/02/17). Later in the unit, the teacher supported students to recall what they read and viewed about Lonnie Johnson and the engineering practices he used when designing the Super Soaker in order to support students to plan and conduct tests of their own toy designs (Unit 2, Lesson 3.8, 03/02/17). Similarly, near the end of the unit of instruction, in order to prepare presentations of their final toy designs to kindergartners, the teacher asked students to recall the ways in which Lonnie Johnson presented his ideas for the Super Soaker design to others (Unit 2, Lesson 5.1, 03/06/17). Again, connecting back to the ideas introduced in these texts supported students' learning and engagement in engineering practices, as well as the teacher's enactment of the unit of instruction.

The *Balloon Rocket Story* played a similar role, serving as a touchstone in the unit, which the teacher and students revisited on multiple occasions. For instance, in the lesson that followed the *Balloon Rocket Story* (Unit 2, Lesson 3.3, 02/08/17) the teacher supported the class to plan their own fair test by connecting to the story, in which the idea of fair tests was introduced. Several days later (Unit 2, Lesson 3.4, 02/21/17), the teacher supported students to interpret the results of their own friction investigation using toy cars, by comparing students' investigation materials and findings to those from the balloon rocket investigation and story (e.g., "Think back to that balloon rocket that we did. How could you compare that with the toys and the launchers?"). During this conversation, one student also made a connection to the "thought experiment" in the story, which explained that different materials or surfaces introduce different amounts of friction. In later lessons, the teacher made additional connections to the *Balloon Rocket Story* to support students' development of scientific models (Unit 2, Lesson 3.6, 02/24/17), and also to demonstrate how students might develop lists of the materials needed to build the toys that they designed (Unit 2, Lesson 5.1, 03/06/17).

This type of coherence was seeded through the design of the curriculum and achieved through its enactment in the classroom. Teachers create coherence by linking materials, activities and contexts in ways that enable students to make rich connections, which can provide interesting and meaningful ways to achieve curricular goals, particularly in the context of integrated instruction (Guthrie et al., 1999). These examples illustrate the ways in which the focal texts and tasks described within this chapter, not only provided opportunities for students to engage in knowledge building and scientific practices as they read and interpreted text but were also productively leveraged throughout the rest of the unit of instruction in service of new learning. Within the third-grade class, the featured texts and tasks served as shared knowledge and experiences, or touchstones, that the teacher and her students were then able to draw and build upon as they engaged in new experiences and learning. Thus, the opportunities afforded by this type of instructional coherence have implications for the continued design of texts and tasks for project-based instruction.

CHAPTER VI: UNIT THREE

How can we help the birds around here survive and thrive?

The instructional context for this chapter is the third *Using Multiple Literacies in Project-based Learning (MLs)* unit of instruction focused on disciplinary core ideas related to heredity, biological evolution, and ecosystems. The unit is framed by the following driving question: *How can we help the birds around here grow up and thrive?* In the unit, students observe birds near their school and homes to study and compare their physical and behavioral traits and life cycles. In addition, students work to explain how birds' characteristics, which result from inheritance of genetic material passed down from parents and interactions with the environment, affect their survival. Concurrently, based on the knowledge students build throughout the unit, the students explore ways in which they can work to support the birds living in their area to survive and thrive (e.g., designing bird feeders to address specific birds' needs). Throughout the unit, students have opportunities to read and interpret a variety of text types, such as live bird cams, informational videos, field guides, informational and narrative texts, maps, and tables.[8]

In the first part of this chapter, I focus on the selection and enactment of a National Public Radio (NPR) video entitled, *Secrets of the Snowy Owl*. In the focal classroom, this video was paired with a video viewing guide designed to support students' viewing and interpretation of the information in the video, as well as to support the teacher's enactment. These resources, in

[8] In the case study classroom, reported on in this dissertation study, this unit of instruction was shortened in order to ensure time for the class to complete portions of all four third-grade MLs units. Additionally, for the purposes of this teaching experiment, some texts and activities that were not included in the larger MLs unit, were added in order to both support a field study of the technology and to pilot additional texts for consideration in the unit.

hand with the lesson plan, were designed to build upon students' firsthand observations of birds around their school and community, and their learning about birds' needs for survival (i.e., food) and behaviors, in order to explain birds' migration patterns. In the second part of this chapter, I focus on the design and enactment of a data table, which reported the number of Snowy Owl sightings in a state in the Midwest (in which the students in the class lived) across two years. The data table was designed to extend and contextualize students' video viewing experience by engaging them in analyzing and interpreting Snowy Owl migration data relative to their local context. Finally, I follow with a description of a text and task in which students engaged following the enactment of the Snowy Owl video and Data Table as a part of an overarching Ornithology Lab, which we called the Migration Case Study.

The Unit of Instruction

In this section, I describe the progression of the PBL unit leading up to the use of the focal texts, in order to situate these text-reading/viewing events within the larger unit of instruction. Following the introduction of the unit driving question, students made observations of local birds' physical traits and behaviors around their school and neighborhoods, as well as through the use of a number of live web- or "feeder"-cams and began to sort or classify the birds they observed based on similarities and differences in their traits. Following students' initial grouping of birds, they were introduced to some of the ways in which ornithologists classify birds based on their traits, such as features of beaks, wings, feet, and migration patterns.

As students continued to observe and compare birds' traits and explain the relationship between their traits and their behaviors, they were introduced to an Ornithology Lab (modified for enactment in the case study classroom), in which students selected a local bird about which they wanted to learn more (e.g., Eastern Screech-Owl, Red-tailed Hawk, American Robin, Baltimore Oriole, etc.). Completed iteratively throughout the unit of instruction, the Ornithology lab consisted of a researcher-selected and designed text set, some of which were unique to each bird (e.g., Field Guide entry, Migration Case Study), and some of which were common across birds (e.g., Wings of Birds, Feet of Birds, Beaks of Birds, and a trade book *Beaks!*). Using these print and digital, multimodal texts at different points in the unit, students worked with a partner, as ornithologists, to classify their selected birds based on wing, beak, and foot shape, as well as migration behavior, and to explain how their birds' traits (i.e., physical features and behaviors) supported survival. To synthesize and communicate their Ornithology Lab findings to others, students created digital, multimodal presentations to share with their classmates, incorporating print text, online and student-drawn images, and videos. Finally, students used this information to inform the design and building of bird feeders to help the birds in their community thrive. The portion of the Ornithology Lab texts and tasks addressed in this chapter is the Migration Case Study, which students completed after exploring migration as a whole class.

The set of lessons featured in this chapter began with students building on their earlier experiences in the unit by making predictions about why they don't see certain birds around their school and neighborhoods during all seasons of the year. After this initial brainstorming, students viewed and discussed a number of images and maps to introduce the idea of bird migration. Next, students viewed and discussed, supported by an interactive viewing guide, *Secrets of the Snowy Owl*, which illustrated ways in which scientists have investigated Snowy Owl migration. The video was paired with a researcher-designed data table, which provided data about Snowy Owl sightings in the students' state during two years in order to further explore patterns in Snowy Owl migration (within and across years). Finally, students built on their experiences and learning about bird migration in these contexts to engage in a Migration Case Study focused on their selected Ornithology Lab bird. The case study required the reading and interpretation of print text, maps, and data tables to explain their bird's migration patterns in a digital, multimodal presentation.

PART I: Secrets of the Snowy Owl Video and Viewing Guide

In this section, I focus on the selection of the video, *Secrets of the Snowy Owl*, and design of an accompanying viewing guide. The video focuses on core ideas related to inheritance and variation of traits and was paired with a researcher-designed data table (see Part II of this chapter), to engage students in the scientific practice of analyzing and interpreting data similar to the kinds of data scientists collected in the video. To address my research questions, I (a) describe the ways in which the selection and enactment of the video and related task supported students' science and literacy learning; and (b) identify modifications to the design of the viewing guide and task that might enhance students' science and literacy learning, in the context of project-based science instruction.

Multimodal perspectives on literacy assume that people use many representational resources or modes, such as images, audio, and video modes, to make meaning (Jewitt, 2008). Lemke (2004) explained that scientific literacy and communication are inherently multimodal, and that scientific disciplines are "leading the way" in the use of video, animations, graphical displays, audio, and simulations to pursue research questions. This integration of print text and multimedia in scientific disciplines illustrates the ways in which scientific and multimodal literacy are fundamentally intertwined. Thus, in order to read, interpret, and produce science text in service of knowledge building and engaging in scientific practices, students must develop skills for interpreting and translating across multiple modes of representation. One goal of *MLs* curriculum design is to provide and support such learning opportunities for young students by incorporating multiple modes of representation, such as videos, into the curriculum as learning tools.

However, little is known about how young students can be supported to engage with and learn from multimodal representations as they learn science. In an exploratory case study focused on fourth-sixth grade students and their teachers, Prain and Waldrip (2006) found that while teachers incorporated multiple modes to engage students in science learning, they did not systematically support students to integrate or translate across modes. Additionally, students required varying levels of support and experiences in order to translate across modes to develop conceptual understanding. Alvermann and Wilson (2011) suggested that teachers might systematically support students to interpret and integrate multimodal science texts is by applying comprehension strategy instruction to multimodal text (e.g., videos, diagrams, models, photographs, first-hand observations), such as by making connections across texts, making inferences, setting a purpose for reading, distinguishing essential from nonessential information, making predictions, visualizing, and monitoring for comprehension.

Selection of the Video and Design of the Viewing Guide: Secrets of the Snowy Owl

The video, *Secrets of the Snowy Owl*, and viewing guide were selected and designed to: (a) illustrate core ideas related to inheritance and variation of traits, (b) provide information that connected to and built upon students' first-hand observations during the unit, (c) illustrate the ways in which scientists have designed and conducted investigations of bird migration, (d) support students to view, interpret, and discuss information presented in diverse media formats (e.g., video), and (e) motivate students' later engagement in the scientific practice of analyzing and interpreting data to make sense of bird migration patterns.

Secrets of the Snow Owl is a nine-minute NPR video, which begins by introducing the problem that scientists know little about Snow Owls' behaviors, including their migration routes, because these birds typically live most of their lives in the frozen Arctic, far away from humans. However, due to changes in their migration patterns, more Snowy Owls have been sighted in the United States in recent years. The video then illustrates the ways in which ornithologists have begun to investigate Snowy Owl migration routes through the use of solar-powered GPS "backpacks." The video then follows the NPR reporter, and narrator of the video, on a road trip to track and locate one Snowy Owl named Baltimore.

The video viewing guide was designed to support the teacher's enactment and to engage students in viewing, interpreting, and discussing the ideas in the video. For this video, the viewing guide consisted of the following five guiding questions, which the teacher previewed prior to viewing and then paused to discuss with students during the video: (1) What are some of the questions that scientists have about snowy owls? (2) Why do scientists think that owls might stop at places like airports that are wide open spaces? (3) What were some of the important kinds of information that the owl sleuth was able to gather through his research? (4) What would be neat about being an animal "sleuth"?

Overview of Enactment

Prior to viewing the video, *Secrets of the Snowy Owl*, the teacher made connections to students' prior learning and experiences in the unit of instruction and revisited the previous days' discussion about why the students only see some birds during certain seasons of the year. After revisiting these ideas, the teacher introduced and invited students to share their thinking about the lesson driving question: *How do scientists study how birds navigate and migrate?* Before beginning the video, the teacher previewed the interactive viewing guide questions with students, and then engaged students in viewing and discussing the ideas in the video, twice.

Table 6.1

Snowy Owl Video Enactment Timeline

Lesson	Day	Lesson Activities
How do scientists study how birds migrate and navigate?	Day 1 50 mins.	• Teacher and students revisit previous day's predictions • Teacher introduces lesson driving question and sets a purpose for viewing • Teacher previews interactive reading guide • Teacher engages students in viewing and discussing the ideas in the video, twice, using the interactive reading guide to support discussion

Testing Conjectures

In analyzing and reporting data specific to the selection and enactment of the *Secrets of the Snowy Owl* video and data analysis task (Part II of this chapter), I foreground the following features of the designed MLs learning environment (i.e., *embodiment*): (a) the designed tools and materials, including teacher supports (i.e., lesson plan, interactive viewing guide) and literacy resources (i.e., video); and (b) the task structure. The *mediating processes* outlined in my conjecture map served as analytic lenses, guiding my analyses of enactment data and interviews. For instance, to understand whether and how *mediating processes* produced *desired outcomes* within this lesson, I drew on transcript and interview data in order to closely analyze the ways in which these *mediating processes* emerged and unfolded in the classroom.

The close analysis of transcribed video of lesson enactment and interview data allowed me to analyze the ways in which the designed tools and materials (e.g., teacher supports, literacy resources) and task structure produced observable interactions: (a) using tools of reading, writing, viewing, and discussing for meaningful purposes, (b) using scientific ideas and practices, (c) building on prior knowledge and funds of knowledge, and (d) the teacher's instructional moves. Analyzing observable interactions revealed within transcript data in combination with interview data, allowed me to examine whether and how the *mediating processes* led to the desired outcomes, including: (a) making sense of and synthesizing multimodal texts and (b) using science ideas and practices to make sense of and explain phenomena. I present my findings in the following section.

Findings

In this section, I present findings from my analyses of enactment data (lesson plans, field notes, transcribed video recordings, and student artifacts) and interview data with focal students and their teacher to respond to my research questions: (1) How did the design and enactment of *Secrets of the Snowy Owl* and task support third-graders' science and literacy learning? (2) How might modifications to the video and task better support third-graders' science and literacy learning, in the context of project-based science instruction?

Findings from enactment. I found that the selection of the video, *Secrets of the Snowy Owl*, and the design of the viewing guide and task synergistically supported third graders' science and literacy learning. I also identified missed opportunities, both within the design of the curriculum resources and the enactment of the lessons, for further supporting the science and literacy learning of all students.

Before viewing: Setting the purpose and preparing to view. Analyses of the written curriculum and transcripts of classroom enactment revealed that the teacher leveraged the video and interactive viewing guide to support students' science and literacy learning by (1) connecting to students' prior knowledge and experiences in the unit, (2) setting a purpose for viewing and making predictions, and (3) using the interactive viewing guide to preview guiding questions in order to support viewing and discussion.

Connecting to students' prior knowledge and experiences. Prior to introducing and viewing the video, the teacher supported students to activate prior knowledge and experiences by revisiting the unit driving question and students' prior learning and experiences in the unit ("Yesterday we came up with a question… In addition to how can we help birds in our community thrive and grow up, what was the question that we talked about yesterday?"). The teacher invited students to share what they recalled about their explorations from the previous day and highlighted specific portions of their initial discussions of and brainstorming about bird migration.

Nick: What way do they migrate?

Teacher: Okay, we wanted to know the direction in which they migrate. We looked at some arrows and some maps. But even before that, what do birds do?

Ellie: In the winter?

Teacher: It's not what do birds do in the winter, because it's not just – remember – it's not just about the winter…We think a lot about winter and migration because we live in [a state in the Midwest], and we even have humans that we call "snowbirds."

Curtis: Because they move from place to place.

Teacher: Alright, they go from here and they head down to Florida in the wintertime.

Student: My grandpa!

Teacher: Yep, my grandparents as well. But what did we talk about Ellie? What was that question that came up?

Ellie: Where do birds go? What do birds do when they run out of food?

Teacher: Okay, when they can't find their food sources. Remember, we listed those food source on the board – the berries, the fish, some of the meats, plants, people food. So, in winter time, it's not that we don't go outside, but we're not necessarily having picnics or hanging out outside and leaving food around. The snow comes or we don't get a lot of sun and so the plants aren't really growing like they do now (early spring), so birds have got to find some other resources for food to survive.

Ellie: And that's what led to the migration theory!

Nick: And that's why they migrate!

This excerpt illustrates the ways in which the teacher activated and drew upon students' prior knowledge and experiences before introducing the video. She began by asking students to recall a question, in addition to the unit driving question, that the class discussed the previous day. The excerpt, above, began with Nick's suggestion that the class asked about the direction birds migrate. In response, the teacher connected to texts the students analyzed and discussed the previous day, a set of maps depicting the migration paths of different birds. As the excerpt continued, Ellie identified a connection between winter and migration. In response, the teacher clarified that we associate migration with winter due to living in the Midwest, where people who move south for the winter months are often referred to as "snowbirds"; however, migration is "not just about winter." Finally, Ellie proposed that another question they class considered was, "What do birds do when they run out of food?" The teacher then summarized the class' previous day's discussion about birds' food sources, which students had been gathering information about through firsthand observations around their school and neighborhoods, through watching web- or feeder-cams in the classroom, and by reading field guides about their Ornithology Lab birds.

After synthesizing this learning to generate a list of important food sources for birds, the class concluded that birds would not be able to find all of the food sources on their list during all seasons of the year (e.g., berries, insects). After the teacher briefly summarized this discussion, Ellie announced, "that's what led to the migration theory!"

Through leveraging the unit driving question (*How can we help the birds around here grow up and thrive?*), drawing on lesson driving questions from earlier in the unit (*What do birds do when they run out of food in their habitats?*), and connecting to earlier unit texts (e.g., migration path maps, student-generated list of food sources) and discussions, the teacher supported students to activate prior knowledge and earlier unit experiences that were relevant to and had the potential to support students' viewing, discussing, and interpreting the information in the video about Snowy Owl migration.

Setting the purpose and making predictions. In addition to activating students' prior knowledge and experiences, the teacher also set the purpose for viewing, invited students to make predictions, and leveraged the guiding questions on the viewing guide to prime students' thinking and to guide their viewing. After revisiting students' prior learning and unit experiences, the teacher said, "Today, I have another question that I want to pose to you and we've got a really neat video to watch," and wrote the following question on the whiteboard: "How do scientists study how birds navigate and migrate?" The teacher then invited students to share their thinking and predictions related to this question, prompting students first to reflect on how the they studied different scientific phenomena throughout the year.

Teacher: Any thoughts about how you think scientists study how birds navigate and migrate? I'm not asking you *how* birds navigate and migrate, but how do scientists study how they do that…You've been scientists all year. Think about what you've done to figure out some of the answers to some of the driving questions that we've had. As scientists…what have we done to study things and how they work and why they do things? Kaylee?

Kaylee: We ask questions and solve them.

Teacher: We ask more questions. So, how do we solve them though? How? …How do we solve some of those questions that we pose or that we ask? Ellie?

Ellie: We do research.

Teacher: Okay, we do some research.

Ellie: We do research and find out more about the birds.

Teacher: Okay, we do research to find out more. How do we do that research? We've done research in a…variety of ways. How have we done some research, Lucas?

Lucas: We've studied structures.

Teacher: Okay, we've looked at specific structures of some animals. What else have we done? Kaylee?

Kaylee: We looked at the videos that you pulled up yesterday and we studied the birds.

Teacher: …Okay, so we make observations. We watch the animals in action, or we pull up videos that we have found on the Chromebooks… What else have we done to figure out how things work or why…? So, we've watched videos, we've made observations. What other units did we do besides anything with animals?

Students: Toys!

Teacher: Toys. How did we find things out with some of the toys? …Bobby?

Bobby: By making them.

Teacher: We *made* toys, right? So, we recreated something, or created something, right?

In this excerpt, the teacher invited students to share their thinking about how scientists might study how birds navigate and migrate, but then asked students to first think about how they, "as scientists," have studied phenomena throughout the year in this and earlier project-based science units. Students shared that they conducted research, made observations to study animals' structures both firsthand and through video, and that they studied other phenomena through designing and building.

After engaging students in reflecting upon their own experiences studying different phenomena, the teacher transitioned back to her original question about how students' thought scientists might "study how birds navigate and migrate."

Teacher: How do you think they study it? Kaylee said they watch videos, they make observations. Bobby?

Bobby: They take pictures.

Teacher: Maybe they take pictures of things that they see, absolutely…

Ellie: They track them by, like they do research about them and then once they find something that they want to know about it, like what their food source is, they could put out the food source and find out what they do to like, they could learn about it and learn like what their structures do.

Teacher: Okay, how they use their structures to eat their food. You started to say something else though. I heard you use the word "track." You said, "They track."

Ellie: They like, and when they find out what their food is, they can track them down by using the food as like a lure.

Teacher: Okay, how do they track certain animals? What do they do to track animals, Cameron?

Cameron: They maybe, like put a bunch of their food out and then they might come to it.

Teacher: But what if they want to know if that's the same animal they were watching last spring? What do they do to track those animals? Carter?

Carter: Smell.

Teacher: Okay, the animals may use their sense of smell. How do the scientists track animals?

Ellie: Videotape behavior.

Teacher: Okay, they do videotape. Yep, absolutely. What else do they do? …Owen?

Owen: They could put like a sticker (inaudible)…

Teacher: Okay, so oftentimes they call them little tags, right?

Owen: Yeah.

Teacher: And often, they identify those. When we go to our rural education day, you'll see that there are some dairy cows there and some of the dairy farms have hundreds of cattle on their farms and they have to tag them with like an earring, they call it. And scientists will do the same kind of thing. They'll see patterns of birds over the course of time. Zayn?

Zayn: …(inaudible) they put like a little camera so they can watch how they fly and see how they like (inaudible)…

Teacher: So, they put like a mini Go Pro on there?

Zayn: Yeah.

This excerpt illustrates the ways in which the teacher invited students to share their thinking and predictions about the ways in which scientists investigate how birds migrate, the focus of the video, *Secrets of the Snowy Owl*. Throughout the excerpt, students proposed a variety of ways in which scientists might study bird migration, including by making video observations, taking photographs, and putting out multiple food sources to test birds' preferences. When Ellie introduced the word "track," the teacher leveraged the opportunity to focus the class on the idea of how scientists might "track" birds to study their migration. Even prior to introducing the video, which illustrates a study in which scientists fitted Snowy Owls with GPS trackers, the teacher was able to draw on students' ideas to move the pre-viewing discussion in this direction, again priming their thinking before viewing and interpreting the ideas in the video.

Using the interactive viewing guide to preview guiding questions. The final way in which the teacher worked to support students' science and literacy learning, before viewing, was by previewing the interactive viewing guide with the students. The lesson plans suggested that the teacher use the guiding questions (introduced previously) to support students' discussion of the ideas in the video. In this case, the teacher also used the guiding questions to frame what students should be listening for as they watched the video by previewing the questions together (e.g., "We're actually going to be listening in the video for questions that scientists have about snowy owls," and "We're going to find out what he was able to figure out.").

While previewing the guiding questions with the class, the teacher also capitalized on the opportunity to clarify unfamiliar vocabulary with students (e.g., sleuth and conduct), introduced in the driving questions and important for interpreting the information in the video.

Hunter: (*Reading from the viewing guide*) How did the owl sleuth conduct his research?

Teacher: What's a sleuth? Can you think of another word for a sleuth? An owl sleuth, Nick?

Nick: Like an owl sleuth.

Teacher: What does sleuth mean?

Nick: Like resource.

Teacher: Not quite, not a resource. Carter?

Carter: Like you can blend in very good.

Teacher: Not quite. A sleuth…is like a detective. How did this owl sleuth conduct? What does conduct mean, Cameron?

Cameron: …I know what it means but I don't really know how to explain it.

Teacher: I would say it, one word, two letters. How did this owls sleuth, one word, two letters, conduct his research? How did he?

Lucas: Found

Ellie: Do

Teacher: "Do" is what I was thinking. How did he conduct his research? How did he go about doing his research?

In this example, the teacher talked with students to unpack one of the guiding questions, prior to viewing the video, in order to ensure that students understood the meaning of the question. The teacher paused to focus on two words, sleuth and conduct. After sampling two students' ideas about the meaning of the word sleuth, the teacher provided a definition: "A sleuth…is like a detective." Following this exchange, the teacher paused again to check students' understanding of the word "conduct," and asked students to provide a simple "one word, two letters" synonym, "do."

During and after viewing: Supporting students to view and interpret information. Analyses of the written curriculum and transcripts of classroom enactment revealed that the teacher leveraged the video and interactive viewing guide to support students' science and literacy learning by using the guiding questions to engage students in discussion and check for understanding of the ideas in the video. The teacher also paused the video, in response to students' comments, in order to clarify information in the video.

Pausing to clarify information in the video. As they viewed the video, many students commented aloud about what they saw on the screen. On one occasion, the teacher paused the video to clarify the images depicted – a snowy owl being fitted with a GPS backpack. When students saw this image, gasped, and commented (e.g., "Poor guy!"), the teacher paused to clarify the image on the screen.

Teacher: Okay, so it's been described to me before; it's kind of like a piercing. It's not the most pleasant, like you know, lots of people get their ears pierced. It's really not that painful. You've all probably had a shot of some sort.

Students: [Gasping]

Teacher: It hurts for a moment, but…I promise you, they are not doing anything to hurt the owls. They're doing it so that we can know more about them, because if we don't know about animals and we don't know how to help them grow up and thrive, what happens?

Students: They die.

Teacher: Okay, they could become extinct. We have to make sure that we're not doing that to them.

In this example, the teacher paused the video to clarify information, in response to students' in-the-moment reactions to the content of the video. When students expressed distress upon viewing the fitting of the GPS backpacks to the Snowy Owls, the teacher paused to compare this event to experiences students were likely familiar with – having their ears pierced or receiving a shot. The teacher also used this opportunity to emphasize some of the reasons scientists wanted to track the owls: (a) to learn more about them, (b) to protect them, and (c) to make sure that humans were not threatening their survival, connecting to the unit driving question.

Following this example, students continued to comment aloud in response to the video and generated and verbalized several questions during viewing (e.g., Why does it [the Snowy Owl chick] look so ugly? Why are they not white when they're born? Why are they grey? Did he name the owl?); however, the teacher did not stop on each of these occasions. Instead, she chose to pause the video in order to discuss the guiding question provided on the interactive viewing guide (see below). The teacher did, however, acknowledge that students' spontaneous questions, which prompted her decision to play the video a second time through, with fewer pauses:

> If we've got time…we'll watch it all the way through. It's only about an 8-minute video, so we'll be able to watch it all the way though…Just like a book, just like any movie

> you've seen, the second time you watch it, you're going to have a lot more things answered… (*During watching the second time through*) If you have questions, flip your paper over and write them down, but as excited as you are about the things you're hearing, if you're talking to your neighbor, they're not able to listen, alright?

As indicated previously, the teacher decided to play the video a second time through, with fewer pauses because students were posing and verbalizing a number of questions as they viewed. In response, the teacher proposed that, "Just like a book, just like any movie you've seen, the second time you watch it, you're going to have a lot more things answered," but did not pause the video to respond each time a student proposed a question. During the second time watching the video, because students continued to speak out during the video and ask questions aloud, the teacher proposed, "flip your paper over and write them down," acknowledging students' excitement about the content and encouraging students to monitor comprehension by recording their questions as they viewed.

Leveraging the viewing guide to support viewing and interpretation. While the viewing guide did not explicitly call for the teacher to pause the video to discuss the information and guiding questions throughout, the teacher chose to pause the video several times in order to engage students in discussing and writing their responses to each of the viewing guide questions. For example, the first time viewing the video, the teacher paused after information related to each of the viewing guide questions was introduced, and asked students to describe what they saw or heard that would help them answer the guiding question. Recall that the first question on the viewing guide asked, "What are some of the questions that scientists have about snowy owls?"

Teacher: Are there any questions that you can tell, based on where we're at in the video, or if you were listening at the very beginning, what are some questions that scientists have about the Snowy Owls? Nick, what did you hear or what did you think? A question that scientists have?

Nick: …where are their resources? Like, where do they live? What part of the owl family do they fit in with?

This brief exchange provides one example of how the teacher paused the video to talk with students about the guiding questions as they viewed, which the teacher did for each question. In this example, the teacher asked students what they heard in the video that would answer the first question on the viewing guide, to which Nick provided a number of responses that the teacher recorded on the white board for the rest of the class to view. The second time viewing the video, the teacher emphasized this question again, and even played this section of the video a third time through, to ask students to listen for the questions scientists asked about snowy owls: "I want to go back just a minute (in the video). Listen to the questions that he's asking." Thus, in addition to playing the video all the way through, with a number of pauses to pose and discuss the guiding questions on the video viewing guide, the teacher also replayed short sections additional times in order to support students to view and interpret key details in the video and to emphasize essential information.

In addition to pausing the video to discuss the guiding questions after relevant information was introduced in the video, the teacher also used the time, during which the video was paused, to preview upcoming guiding questions in order to prompt students' to be listening for specific information as they viewed and listened (e.g., "Okay, just so you're listening, the next question is, 'What were some of the important kinds of information that the owl sleuth was able to gather through his research?'"). Thus, in addition to previewing all questions with students prior to viewing the video, previewing the questions individually as the video played is another way in which the teacher leveraged the viewing guide to support students' strategic viewing and interpretation of the ideas presented, by priming students to be watch and listen for essential information.

Finally, while the first three questions on the viewing guide were designed to support students to view and identify key details in the video related to questions scientists have about snowy owls, scientists' predictions about snowy owl behavior, and the data that the "owl sleuth" gathered and used in the video, the final question asked students to make a personal connection to the content in the video: (4) What would be neat about being an animal "sleuth"? Recall that the class worked together to unpack the meaning of the word "sleuth" prior to viewing the video. Additionally, while the teacher paused the video to engage students in talking about the answers to the first three guiding questions, students responded in writing and shared their ideas about the fourth viewing guide question only after the class' second time watching the video through. Students' responses to this question provided additional evidence that students were able to make sense of the complex ideas in the video with the support of the teacher and the viewing guide:

Keyanta: Learn about snow owls.

Zayn: …you get to follow them and you get to see the whole world.

Hunter: You get to go to those places just because they have been there.

Ellie: Getting close up to wild animals.

Owen: That I could follow different animals around and learn where they live.

Raven: Learn more about different kinds of animals and how they live and where their habitat is.

Rachel: To learn about all kinds of animals.

Nick: You get to make history discovering new birds.

Brody: That you get to track them.

Kaylee: That you get to talk to other people who have seen them.

After sampling a number of students' ideas about why they thought it would be neat to be an "animal sleuth," similar to the narrator in the video, the teacher summarized, "You meet other people. You interview other people, absolutely…Lots of little mini jobs involved in being an animal sleuth: reporter, scientists, data collector…traveler." The question was not only useful for gauging the extent to which students understood the work of the "owl sleuth" in the video, but also because the four third-grade *MLs* PBL units were designed to position students, not only as learning about science, but also as *doing* scientific work and engaging in scientific practices. In addition to providing evidence that students were able to view and interpret the ideas in the video, students' responses provided evidence that the third-graders were able to envision themselves in the role of "animal sleuth," and to describe why they thought this would be interesting scientific work.

Constraints of the video, viewing guide, and task revealed through enactment. In addition to the ways in which the video, viewing guide, and the teacher's enactment supported students' science and literacy learning, my analyses also revealed limitations of the design and enactment of the written curriculum. One limitation related to the design of the viewing guide and the teachers' enactment was that both during and after viewing the video multiple times, there was no focused return to the idea of migration and the ways in which the information in the video might build upon students' prior learning about migration. Particularly after the rich discussion enacted prior to viewing the video, in which the teacher supported students to activate prior knowledge and experiences by revisiting the unit driving question and students' prior learning and experiences related to migration, not making the connection back to this discussion during or after viewing was a missed opportunity that has implications for the redesign of the viewing guide. For instance, in addition to providing guiding questions which serve to focus the teacher's enactment and students' attention on essential information in video, we have begun to also identify specific times to pause videos and suggest ways in which teachers might support students to make connections between their previous learning and experiences and ideas in the video. This type of support may be particularly important for elementary-grades teachers who have multiple subjects for which to prepare instruction, and limited planning time to do so.

Additionally, throughout the lesson, the teacher commented on students' excitement as they viewed and discussed the video. One way in which this excitement manifested was through students spontaneously and frequently turning to talk to their neighbors about the content of the video and through commenting or asking questions aloud about the information in the video as it played. While the engagement in and excitement students displayed in response to the video is encouraging, it is possible that students' calling out and side conversations hindered some students' viewing and interpretation of the video. This also has implications for the design of the teaching guide, which could be revised to identify and provide suggestions about opportunities for all students to talk about the ideas in the text with their peers using multiple participation structures to support sense-making.

A final limitation revealed through enactment, and perhaps related to the previous two limitations described, was the limited time available for the enactment of the lesson. For instance, if the teacher had more time to dedicate to engaging students in viewing and discussing *Secrets of the Snowy Owl*, it is possible that she would have chosen to use that time to support students to make the connections back to the ideas they had previously discussed about migration and the lesson driving question (i.e., How do scientists study how birds navigate and migrate?), and also provided time for students to engage in various participation structures to support students to talk with their peers in response to the guiding questions or to students' own questions about the information in the video.

Conclusion

The findings described in Part I of this chapter illustrate the ways in which the video, the viewing guide, and the enactment worked in interplay to create opportunities for and to support students' science and literacy learning. There appeared to be affordances associated with the selection of the video, the design of the viewing guide, and the placement of the video and related tasks (related tasks are discussed further in Part II) in the curriculum. For instance, because the video was selected and placed in the curriculum due to the ways in which its content connected to and had the potential to build upon students' prior – and support students' future – learning related to bird migration and the ways in which scientists plan and conduct investigations, the teacher was able to leverage the video for these purposes. While I identified missed opportunities with respect to supporting students to make explicit connections to and build upon their prior knowledge specific to bird migration, there was also evidence that the teacher and students used the guiding questions on the viewing guide support knowledge building related to how scientists investigate bird migration.

While research on the use of multimodal text with young students in the context of science learning is limited, Prain and Waldrip (2006) argued that learners need explicit support to strategically approach the reading and interpretation of multimodal text in order to make meaning from multiple representations to build science knowledge. Alvermann and Wilson

(2011) suggested that one way that teachers might systematically support students to interpret and integrate information across multimodal science texts is by applying conceptions of comprehension strategy instruction to multiple modes of representation, such as video. My findings in Part I of this chapter provide some evidence of the utility of such an approach with young students, when used with video text, by illustrating the ways in which the teacher made explicit and supported students to use a variety of comprehension strategies in the context of viewing and interpreting the video, such as by activating prior knowledge, setting a purpose for reading, distinguishing essential from nonessential information, and monitoring for comprehension. In Part II of this chapter, I turn to another form of representation – a data table – which students analyzed and interpreted following their viewing of *Secrets of the Snowy Owl*.

PART II: Snowy Owl Data Sightings Data Table

In this section, I focus on the design of a data table, which provides information about the number of Snowy Owl sightings in a state in the Midwest (where the students in the case study classroom lived) during two years, 2007 and 2016. The table was designed to both extend students' learning from the video, *Secrets of the Snowy Owl* (see Part I of this chapter), and to engage students in the scientific practice of analyzing and interpreting data to make claims. Students had opportunities to create and analyze their own data tables during the second *MLs* unit (*How can we design fun, moving toys that any kid can build?*) in the context of planning and conducting investigations with toys, but the Snowy Owl data table was students' first opportunity to analyze this amount and range of data (24 data points that ranged from 0-504). To address my research questions, I (a) describe the ways in which the design and enactment of the data table and task supported students' science and literacy learning; and (b) identify modifications to the design of the data table and task that might enhance students' science and literacy learning, in the context of project-based science instruction.

Design of the Text: Snowy Owl Sightings Data Table and Migration Case Study

The data table, *Number of Snowy Owl Sightings in [Midwestern State] in 2007 and 2016*, was designed to: (a) illustrate core ideas related to inheritance and variation of traits (e.g., in birds, migration is a behavioral trait that is both inherited and learned), (b) provide information that connected to and built upon students' first-hand observations and other texts (e.g., *Secrets of the Snowy Owl*) in the unit, (c) engage students in the scientific practice of analyzing and interpreting data, and (d) both motivate and serve as a scaffold for students to complete a Migration Case Study about their selected Ornithology Lab bird, for which they would work with a partner to analyze and interpret a similarly designed data table in order to make claims about the migration patterns of their own bird.

The information in the table was based on bird sighting data compiled from eBird (ebird.org), an online checklist program created by the Cornell Lab of Ornithology and the National Audubon Society. The website provides data about the abundance and distribution of birds based on observations entered by both professional and recreational bird watchers, and is shared with and used by educators, ornithologists, and biologists. The table included three columns: (a) month, (b) 2007, and (c) 2016. The first column included twelve rows – one for each month of the year (January through December); the second column included the number of snowy owl sightings reported in the state during each month of 2007; and the third column included the number of snowy owl sightings reported in the state during each month of 2016 (see Figure 1, below).

Number of Snowy Owl Sightings for ☐ in 2007 and 2016

Month	2007	2016
January	19	358
February	9	504
March	3	268
April	0	94
May	0	23
June	0	8
July	0	27
August	0	19
September	0	1
October	0	0
November	0	16
December	0	175

*Data retrieved from ebird.org

Figure 6.1. Snow Owl sightings data table students analyzed and interpreted during the lesson.

Data from multiple years (2007 and 2016) were included in the table in order to design an intertextual connection to information presented in the video, which described that in recent years, the United States has seen an increase in Snowy Owl sightings. Thus, the table was designed to create an opportunity for students to analyze and interpret local (i.e., state) data related to migration patterns of Snowy Owls, both within a single year and across multiple years. The years 2007 and 2016 were selected in order to illustrate the dramatic differences in Snowy Owl sightings reported between the two years. Additionally, the year 2016 was selected because it was the most recent calendar year, prior to enacting the unit.

As introduced in Part I of this chapter, scientific literacy and communication are fundamentally multimodal, meaning that scientists draw on multiple representational forms to build and communicate knowledge about phenomena (Lemke, 2004). Different modes, such as video, simulations, audio, graphical displays, and print text, each have different affordances for communicating scientific information. For instances, data tables allow for major features of large quantities of data to be summarized in an accessible form and have the potential to extend students' experiences of phenomena by provide opportunities for students to analyze and interpret data beyond that which they can collect firsthand (NRC Framework, 2013). NGSS calls for students in grades three through five to "Analyze and interpret data to make sense of phenomena using logical reasoning, mathematics, and/or computation" (NGSS Lead States, 2013, Appendix F). While, across MLs units, students collected, organized, and analyzed their own data collected during firsthand investigations, the Snowy Owl data table represented a larger set of data than students had worked with previously, and extended students' experiences in the unit by providing data that could not be collected firsthand.

Overview of Enactment

Recall that prior to the lesson in which students analyzed and interpreted the Snowy Owl data table, they viewed and discussed the video, *Secrets of the Snowy Owl*, supported by an interactive viewing guide and the teacher's enactment. The video included information about questions scientists have about Snowy Owls, Snowy Owl migration, and changes in their migration patterns. Thus, the video provided the context for and motivated students' analysis and interpretation of the Snowy Owl data table.

After viewing the video, on the next day of science instruction, the teacher introduced the data table, provided time for students to read and interpret the information in the table independently and discuss what they noticed about the data with a partner, before analyzing and interpreting the data as a whole class. To conclude the lesson, the teacher supported students to co-construct a claim about the patterns they noticed in the sightings reported in their state across the two years included in the table.

While a supplemental text, modified from a news article, was also included in the curriculum materials for this lesson the teacher chose not to include it due to time constraints.

The article was entitled, *Fewer Snowy Owl Sightings Expected in [Midwestern State] in 2017*, and was designed to extend and supplement students' analysis and interpretation of the data table. The news article provided additional scientific data to contextualize the Snowy Owl sighting data that students analyzed, and described scientists' predications and explanations of Snowy Owl migration behavior based on current evidence.

Because the teacher did not use the modified news article with the class, students moved directly to the Migration Case Study portion of their Ornithology Labs. Recall that the Migration Case Study that followed the enactment of the Snowy Owl data table focused on students' selected Ornithology Lab birds. The case study texts that students explored included print text, images, maps, and data tables that provided multimodal information about their bird's migration behaviors. After reading and interpreting the text set, each pair of students created a short digital, multimodal presentation (including text, images, and video that students searched for and selected through conducting a Google Image and/or YouTube search) to communicate their findings.

Table 6.2

Snowy Owl Data Table and Migration Case Study Enactment Timeline

Lesson	Day	Lesson Activities
How do scientists study how birds migrate and navigate?	Day 1 45 mins.	• Students read and interpret chart individually (~2 minutes) • Students turn-and-talk to a partner about what they "notice" about the data in the table • Teacher engages students in reading, discussing, and interpreting the data in the table as a whole class • Students co-construct a claim based on how the data is different across the two years represented in the table
How can we describe the migration patterns of different birds?	Day 2 45 mins.	• With a partner, students read, interpret and synthesize print text, migration maps, and data tables about their selected bird for Ornithology Lab migration case study (*Note:* Students had additional opportunities to revisit and continue work on migration Ornithology Lab entries at later points in the unit.) • Volunteers share and discuss initial migration case study findings with the class

Testing Conjectures

In analyzing and reporting data specific to the design and enactment of the *Snowy Owl Data Table* and the data analysis evidence-based claim, and migration case study tasks the followed, I foreground the following features of the designed MLs learning environment (i.e., *embodiment*): (a) the designed tools and materials, including teacher supports (i.e., lesson plans), student notebooks, digital tools, and literacy resources (i.e., data table); and (b) the task structure. The *mediating processes* outlined in my conjecture map served as analytic lenses, guiding my analyses of enactment data, artifacts, and interviews. For instance, to understand whether and how *mediating processes* produced *desired outcomes* within this lesson, I drew on transcript, class- and student-pair artifacts (i.e., evidence-based claim, migration case study), and interview data in order to closely analyze the ways in which these mediating processes emerged and unfolded in the classroom.

The close analysis of transcribed video of lesson enactment allowed me to analyze the ways in which the designed tools and materials (e.g., teacher supports, literacy resources) and task structure produced observable interactions: (a) using tools of reading, writing, viewing, and discussing for meaningful purposes, (b) using scientific ideas and practices, (c) building on prior knowledge and funds of knowledge, and (d) the teacher's instructional moves. Analyzing observable interactions revealed within transcript data in combination with student- and class-generated artifacts, allowed me to examine whether and how these mediating processes led to the desired outcomes, including: (a) making sense of and synthesizing multimodal texts, (b) using science ideas and practices to make sense of and explain phenomena, and (c) develop increasingly sophisticated written and visual artifacts. I present my findings in the following section.

Findings

In this section, I present findings from my analyses of enactment data (lesson plans, field notes, transcribed video recordings, and student artifacts) and interview data with focal students and their teacher to respond to my research questions: (1) How did the design of the data table and task support third-graders' science and literacy learning? (2) How might modifications to the text and task better support third-graders' science and literacy learning, in the context of project-based science instruction?

Findings from enactment. I found that the design of the data table and task synergistically supported third graders' science and literacy learning. I also identified missed opportunities, both within the design of the curriculum resources and the enactment of the lesson, for further supporting the science and literacy learning of all students.

Introducing the data table and initial analyses. In contrast to the teacher's introduction to and preparing students to view *Secrets of the Snowy Owl* the previous day, the introduction to the data table was brief. The teacher introduced the data table by telling the students that she wanted them to look at it and make observations and then talk to one another about what they noticed:

> I just want you to look at it. Look at the heading. Look at the numbers. I just literally want you to take like two minutes: start looking at this and make…some of your own observations. Then, I'll give you time to talk to each other about what you are observing, what you are noticing…So, [that was] about 126 seconds. What are some things you noticed? Talk with each other for, I'll give you 90 seconds… What did you notice about those numbers and sightings?

As students turned and talked about their observations with their peers sitting next to them, the teacher circulated around the classroom, listening in on and joining students' conversations about what they noticed in the data table.

Teacher: What's something that you guys noticed?

Caden: I noticed that there was only 31 snowy owls in 2007.

Teacher: Only 31 total in 2007, okay. Compared to what?

Owen: Compared to this. There's like…900.

Teacher: A lot lot more, right? Okay, so you're going to estimate at about 900 or 1000.

This example illustrates how the teacher collected students' initial interpretations of the data table and began pressing students to compare data across the two years, as she circulated and dropped in on students' conversations, prior to leading a discussion about the data with the whole class. In this example, Caden shared his calculation of 31 snowy owl sightings in 2007. The teacher immediately pressed for the group to compare this to the number of snowy owl sightings in 2016, which Owen estimated to be 900. The teacher conducted similar conversations with other groups before pulling the class together to compare students' interpretations of the data in the table.

Analyzing and interpreting data as a class. After students had time to analyze and interpret the data independently and to share and compare their thinking with their peers, the teacher pulled the class together to further discuss the information in the table. In this context, the teacher supported students to analyze and interpret the data table as a class by (1) collecting and leveraging students' noticings to support sense-making and analysis, (2) pressing students for use of precise language to communicate ideas, and (3) sending students back into the data, focusing on "how" instead of "why."

After pulling the students together to read and discuss the data table as a class, the teacher began by collecting students' noticings, allowing the information that students identified as salient to drive the direction of their discussion and the class' interpretation of the data. After inviting a student to share what they noticed, the teacher followed up with additional questions to prompt them to elaborate on their thinking, support them to re-read and interpret the information in the table, and press students to use precise language in communicating their ideas with the class. One exchange in particular, illustrated each of these moves:

Teacher: Nick, what's something that you noticed?

Nick: That…in 2017, when they didn't really know…the snowy owls that well…but in 2016, when they know the snowy owls more well, more of them came than in 2017, when they didn't really know them, less came.

Student: It was 2007.

Nick: '07.

Teacher: Okay, so when you say they didn't know the Snowy Owls?

Nick: They didn't like know what they ate or like, they didn't know.

Teacher: So, let's look at the title. Let's start with the title. What does the title say that this is representing?

Nick: Sightings.

Teacher: Okay, let's read the whole title: *Number of Snowy Owls Sightings for [Midwestern State] in 2007 and 2016*. So, this doesn't have anything to do with the fact that they didn't really know about the Snowy Owls.

Nick: I'm saying like that less came when they went in 2017.

Teacher: 2007. It's not 2017. That's okay, but certainly when you're repeating information back, you want to make sure it's accurate, right?

Nick: In 2007, they didn't know the birds.

Teacher: It's not that they didn't know the birds. In 2007, what do you notice about that compared with 2016?

Nick: There was only three birds sightings. There was only three months that they saw birds.

Teacher: There was only three months in 2007, and it's not just birds, but it's specifically the Snowy Owls, alright?

After the teacher asked what he noticed about the data, Nick began this exchange by describing differences in the data across the two years represented. While he correctly identified that more snowy owls were sighted in 2016, he provided his own reasoning about *why* he thought there were differences in sightings across the two years, misidentifying 2007 as 2017. Another student followed by providing the correct date, and the teacher probed Nick's thinking about what he meant by saying "they didn't really know about the Snowy Owls." After Nick further explained his thinking, the teacher directed the class back to the title of the table, which she read aloud to the class and clarified that, the table does not provide information about whether or not people knew the Snowy Owls. As this exchange continued, the teacher emphasized the importance of making sure that when students are repeating information from the table, they are communicating the information, accurately. Once more, after Nick again made the claim that people did not "know the birds" in 2007, the teacher directed students' attention back to the table and reframed the question to focus on the information provided in the table: "It's not that they didn't know the birds. In 2007, what do you notice about that compared with 2016?" In a final move to support using precise language to communicate ideas, when Nick claimed, "There was only three months when they saw birds [in 2007]," the teacher emphasized the idea that the data table provides information specifically about Snowy Owls, not just birds in general (e.g., "It's not just birds, but it's specifically the Snowy Owls.").

In the previous example, the noticing that Nick shared focused on comparing the number of Snowy Owl sightings across the two years of data provided. As the whole-class discussion continued, the teacher engaged the class in sharing and comparing additional noticings and analyses. My analyses of transcripts from this portion of the discussion revealed that students shared the following types of observations and analyses: (a) calculations of the total numbers of sightings within a year, (b) connections between the number of sightings and their knowledge of weather patterns (e.g., temperature) in their state, and (c) portions of the data that they found surprising or unexpected. Similar to the exchange between Nick and the teacher, as additional students shared their observations with the class, the teacher continued to follow up with questions to prompt students to elaborate on their thinking, support them to re-read and interpret the information in the table, and press students to use precise language in communicating their ideas. See Table 6.3 (below) for additional examples of students' noticings and analyses related to these categories.

Table 6.3

Noticings Students Shared During Whole-Class Discussion

Types of Noticings	Examples from Enactment Transcripts
Calculations of the total number of sightings	Raven: I noticed in 2007, it only had 31. Teacher: Only had 31 what? Raven: Sightings. Teacher: Of?

within a year	Raven: Of the Snowy Owl.
	Owen: The whole number of 2016 is 1,296.
Connections between data and local weather patterns	Ellie: That in January, February, and March there are…only a couple, but they're Snowy Owls and usually they like places that are cold and usually, in [Midwestern state], it's really cold then, but in the places that are colder, like November and December, they have zero sightings in 2007.
Data that were surprising or unexpected	Zayn: I notice, in 2007, their highest is 19, and then in 2016, in February, its 504. But, in February 2007, there's only 9, and in '17, there's more than in February and then you'd think that January would be higher than February, but February is higher than January.

Recall that the data table was intentionally designed to reflect Snowy Owl sighting data from the students' home state. One noticing shared by a student that illustrated the ways in which this design feature served as an affordance for sense-making was the connection that Ellie identified (see Table 3 above) between the patterns in the data table and local weather patterns. The following excerpt illustrates the ways in which Ellie drew upon her prior knowledge of temperature patterns in different months of the year and features of Snowy Owls' habitat to make sense of the data in the table.

Teacher: What was another observation that you made, Ellie?

Ellie: That in January, February, and March there are…only a couple, but they're Snowy Owls and usually they like places that are cold and usually, in [Midwestern state], it's really cold then, but in the places that are colder, like November and December, they have zero sightings in 2007.

Teacher: Oh, in 2007…So, there were definitely, knowing what we know based on what we kind of read (the video, *Secrets of the Snowy Owl*) yesterday, the Snowy Owl actually goes to what kind of places during the summer?

Ellie: Cold.

Teacher: Colder places. So, it's definitely, it was definitely here during our colder months in 2007.

In this excerpt, Ellie shared with the class that she noticed that it is cold in [Midwestern state] during the months of January, February, and March and "Snowy Owls…like places that are cold." She also observed that in 2007, there were a few sightings of Snowy Owls in those months, but not during other cold months, like November and December. The teacher then identified a connection between Ellie's observation and the video that the class watched during the previous day of instruction and reminded the class that the Snowy Owl's summer habitats are places that are cold, like the Arctic tundra.

As the conversation continued the teacher led the class in identifying the months associated with different seasons of the year, but she did not return to the connections between Snowy Owl sightings and seasons that Ellie introduced to support all students' analysis and interpretation of the data through this lens, which could have been particularly helpful for connecting the data in the table to patterns in snowy owl migration. While Ellie spontaneously drew on her own background knowledge of weather patterns in her state and her learning about Snowy Owl's habitats from the video, it is not clear that other students were making these same connections. This observation has implications for modifications to the design of the curriculum to both explicitly identify the rationale behind the design of particular texts and to support the teacher to leverage the local context of the table as a design affordance in instruction in order to support students to bring multiple sources of prior knowledge to their analyses and interpretation of the data in the table.

Using data as evidence to make a claim. After discussing students' observations and analysis of the data table as a whole class, the teacher engaged students in using the data in the table as evidence to make a claim about how Snowy Owl sightings changed between 2007 and 2016. In this context, the teacher supported students to make an evidence-based claim by (1) supporting students to develop a shared understanding of claim and evidence, and (2) leading the co-construction of an evidence-based claim.

Developing a shared understanding of claim and evidence. After discussing students' observations and analysis of the data table, the teacher transitioned to the task of using the data in the table as evidence to make a claim about how the data changed between the two years. The teacher introduced this task by revisiting what it means to make a scientific claim, and by supporting students to distinguish between a claim and evidence.

Teacher: Look at that information. What claim, remember, what's a claim?

Carter: When you've got your own thought from the graph.

Teacher: Not necessarily, that would be…

Carter: Oh, stuff that you find from the thing that you're looking at!

Teacher: Okay, stuff that you find from the thing that you're looking at. Let's be a little bit more specific… When we're making a claim, what are we doing? We're not asking a question when we're making a claim… Ellie?

Ellie: A claim is (inaudible)…

Teacher: You need evidence in your claim. You're remembering that word, evidence. But a claim…

Ellie: A statement.

Teacher: A claim is like a statement – what you think based on the evidence that you have, alright. So, work together…It says, "Using this data, what claim can you make about how the number of Snowy Owl sightings in

> [Midwestern state] have changed from 2007 to 2016. Support your claim with evidence from the table."

In this excerpt, the teacher asked the class to recall what it means to make a claim. Carter first responded that a claim is "When you've got your own thought from the graph." The teacher began to address Carter's idea, but he quickly interjected with a revision: "Stuff that you find from the thing that you're looking at!" The teacher accepted this response, but pressed the class for more specificity, asking, "When we're making a claim, what are we doing?" After the teacher clarified that evidence is related to your claim and Ellie added that a claim is "a statement," the teacher repeated this idea and elaborated that a claim is "What you think based on the evidence that you have."

At this point in the curriculum, Unit 3, the third-grade students had participated in several scaffolded experiences with using various types of data to make claims based on evidence. Scientific claims and evidence are important components of scientific explanations. The explanation framework used in the *MLs* curriculum has three components: claim, evidence, and reasoning. McNeill and Krajcik (2008) explained that the "*claim* makes an assertion or conclusion that addresses the original question or problem about a phenomenon. The *evidence* supports the student's claim using scientific data…The *reasoning* links the claim and evidence and shows why the data count as evidence" (p. 123). For the task associated with students' analysis of the Snowy Owl data table, students were prompted only to make a claim and to use scientific data as evidence to support their claim about how the number of snowy owl sightings in Michigan changed from 2007 to 2016.

The excerpt above, featuring Carter and Ellie, illustrate some of the challenges associated with learning scientific literacy and language practices, such as developing scientific explanations, to communicate information about phenomena based on analyzing data. In this case, these challenges began with working to develop a shared understanding of what it means to make a scientific claim, supported by evidence. However, this excerpt also illustrates the ways in which the teacher worked to support student to develop an understanding of the roles of claim and evidence in explaining a phenomenon. For instance, Carter's first suggestion that a claim is "when you've got your own thought from the graph," can possibly be traced to when students' used graphs as data representations in order to identify patterns and write explanations based on data from investigations in Unit 2. Carter later modified his suggestion, proposing that a claim is "stuff that you find from the thing that you're looking at." While this description lacks the specificity that is integral scientific language, it is not difficult to see the overlap in meaning of Carter's description and that of McNeill and Krajcik (2008): "The *claim* makes an assertion or conclusion that addresses the original question or problem about a phenomenon" (p. 123).

Recall that the teacher then pressed for more specificity, and supported students to differentiate between claim and evidence, finally concluding that "A claim is like a statement – what you think based on the evidence that you have." In her work with fifth-graders, McNeill (2011) found that when provided with scaffolded learning experiences, elementary students developed stronger understandings of scientific practices and ideas, such as evidence and explanation, over the course of a school year. While it is clear that students' understandings of scientific claims and evidence, in the context of using the Snowy Owl data table, were still just beginning to develop, it is also clear that they were building upon some prior knowledge of these practices as they approached this task.

After introducing the task as a whole class, the teacher circulated as students began to develop their evidence-based claims and conferred with individuals and groups. The teacher used this is an opportunity to further support students' understandings of and to distinguish between claims and evidence and continued pressing on these ideas as she invited students to share out their initial claims with the class.

Teacher: What were some claims that you had, Keyanta?

Keyanta: …That in January 2007, we only had 19 Snowy Owls, but in 2016, we had 258 Snowy Owls last year.

Teacher: So, that sounds like your evidence, right? You're giving facts. So, what could you say about the number of sightings in 2007 and 2016 based on what you just told me? ...What could you say about the number of sightings? …It says, "Using this data, what claim could you make about how the number of Snowy Owl sightings in [Midwestern state] have changed from 2007 to 2016?" How did the number of sightings change?

Keyanta: Oh!

In this excerpt, instead of making a claim to address the question, Keyanta only reported evidence. The teacher identified this (e.g., "That sounds like your evidence…you're giving facts.") and then pressed Keyanta to first develop a claim that answers the question posed*."*

Co-constructing an evidence-based claim. After allowing time for students to develop initial claims with independently or with a partner, the teacher pulled the class together in order to lead the co-construction of an evidence-based claim. In this excerpt, Nick served as the teacher's primary co-construction partner, although there is occasional evidence of additional students' direct participation.

Teacher: I want to know, what do these two years tell you about the number of sightings?

Nick: That the number of sightings in 2017…

Teacher: We're not talking about 2017.

Nick: I mean 2007. We only had 31 sightings, but it increased.

Teacher: So, the numbers did what? What did you say?

Nick: Increased

Teacher: The number of sightings increased. Show me what increased means (*the students make hand motions to demonstrate the meaning of increased*). I see Nick showing me, I see Zayn and Ellie showing me. Okay, increased means to get what?

Students: Bigger!

Teacher: Bigger… So, the number of sightings increased. Keep going, Nick.

Nick: From 2016, they increased.

Teacher: From 2007.

Nick: From 2007 to 2016, the numbers increased.

Teacher: And we know this why? This is our evidence.

Nick: We know this because when we added the numbers up in 2007, and they had less than the first number in 2016.

Teacher: So, could I say there were a lot less?

Nick: Yes, there were a lot less.

Teacher: The numbers were much smaller…

Nick: In 2007.

Teacher: In 2007. We know this because there were (*scribing on the board while speaking*) a lot less sightings in 2007. And you could get a little bit more specific by saying there were only 31, total, versus over 100 in one month alone.

Nick: In the first month of 2016 had more than…all of 2007.

Teacher: Yes, one month alone, in January, had more than all of 2007.

This excerpt represents a portion of the conversation during which the teacher led the co-construction of an evidence-based claim, drawing upon the initial claims students began to develop either individually or with a partner. The teacher first clarified the relevant data as 2007 versus 2017, which Nick misrepresented frequently throughout this lesson, and then invited Nick to make a claim that answered the focal question. When Nick replied that the number of Snowy Owl sightings increased, the teacher clarified what it means "to increase" with the class and then pressed for evidence to support the claim.

Explaining phenomena involves important scientific practices and discourse, such as analyzing and interpreting data and using data to make claims based on evidence. To learn and do science, students must learn to navigate and use scientific discourses (Moje et al., 2001). However, research suggests that this is challenging work for young students. In their work studying middle school project-based science curriculum, Moje et al. (2004), found that students experienced difficulties with analyzing, interpreting, and communicating data, as well as with developing scientific explanations.

As the findings reported in Part II of this chapter suggest, using the data table text to engage in these practices was also challenging for third-grade students and required significant support from the teacher. At the same time, the findings reported here are also promising, in that, when supported by the teacher, the instructional context, and the curriculum materials, students' contributions during class discussion revealed that students had certain intuitions about reading and interpreting the data table and were able to use the table to identify patterns in the data, make numerical calculations and comparisons, make connections between the data and their prior knowledge, and identify data points that they found to be surprising or unexpected. In addition, the teacher pressed students to elaborate on their ideas, use precise language to communicate their ideas, and to re-read the information in the table to clarify confusion. Finally, the teacher scaffolded students' use of the data in the table to make an evidence-based claim to communicate their analyses.

Applying learning to Migration Case Study birds. Recall that the Snowy Owl data table was, in part, designed to motivate and serve as a scaffold for students to complete a Migration Case Study about their selected Ornithology Lab bird. For this task, students analyzed and interpreted a similarly designed data table in order to make claims about the migration patterns of their chosen bird in their home state. It is important to note that while the design of the Migration Case study data tables was similar in format to the Snowy Owl data table, the case study tables were simplified by only including the sightings of their bird from one year. In this section, I report on focal students' responses to the following two questions from the Migration Case Study artifacts, which required students to analyze and interpret the data in their table: (a) In what month was your bird seen the <u>most</u> times in [Midwestern state] in 2016? Use data to support your response; and (b) In what month was your bird seen the <u>fewest</u> times in [Midwestern state] in 2016? Use data to support your response.

Analysis of students' responses revealed that 12 of the 16 focal students were able to use the data table for on their Ornithology Lab bird to identify the month(s) during which their bird was sighted the most and fewest times in their home state. Alternatively, only 6 of the 16 focal students provided numerical data from the table as evidence to support their responses. Of the 10 focal students that did not include data in their responses, (a) two included hypotheses about why their bird was sighted the most and fewest times during certain months (e.g., "April maybe because it starts to get warmer."); (b) one made reference to the chart as providing evidence, but did not incorporate data (e.g., "may I know because I looked at the chart."); (c) three only included the month, with no additional information; (d) one provided a response that did not address the question (e.g., "The eastern screech-owl reported living in [Midwestern state]."; and (e) three did not provide any response to the questions.

Students' responses to these questions suggest that while they were able to read and interpret the data tables in order to identify the months during which the most and fewest sightings of their Ornithology Lab birds were reported, most students needed more support to use data from the tables in order to support their responses. Because students would have had to use this information in order to make a claim about which months represented the most and fewest sightings of their bird, it is unlikely that students were *not able* to identify and interpret this information in the tables. It is possible, however, that students in the class did not have a shared understanding of what it meant to "use data to support your responses." I argue that this is particularly likely based on some students' alternative responses to this prompt, such as providing hypotheses about why the most or fewest birds were sighted during a particular month or referencing the chart but not providing numerical data.

Constraints of the data table and task revealed through enactment. In addition to the ways in which the data table, the tasks of analyzing and interpreting the data and writing an evidence-based claim, and the teacher's enactment supported students' science and literacy learning, my analyses also revealed limitations of the design and enactment of the written curriculum, which suggest design modifications that might better support the learning of all students.

One limitation related to the design of the lesson and the teacher's enactment, similar to a limitation identified in Part I of this chapter, is that there was no explicit return to the idea of migration or the ways in which the information in the table could support students to build a deeper understanding of bird migration. While the "Wrap up" portion of the lesson plan called for a discussion about students' "new understanding about migration," this portion was not enacted. Indeed, analyses of the field notes and transcripts of enactment revealed that the word "migration" was not mentioned by any of the students or their teacher throughout the duration of this day of instruction. Despite this finding, analysis suggests that at least some students were making connections to their knowledge of Snowy Owls and migration (e.g., Ellie's observation that Snowy Owls are typically found in places that are cold and that there were more sightings of Snowy Owls during colder months).

Although part of the intent of the design and inclusion of the data table was to provide opportunities for students to identify Snowy Owl migration patterns within single and across multiple years, this was not fully taken up in the context of enactment. This suggests that the teacher and students might have benefitted additional from prompts within the curriculum (e.g., either within the lesson plan or written directly on a student sheet) that introduced these ideas more explicitly. Such questions might have included the following: (1) What patterns do you notice for Snowy Owl sightings in year X? What does this tell you about Snowy Owl migration in this year? (2) How was the data similar and different in 2007 and 2016? What does this tell you about Snowy Owl migration in both years? Questions, such as these, could have supported students to explicitly connect their understandings of migration to their analyses and interpretation of the data in the table.

In addition to missing opportunities to leverage students' current understandings of bird migration to support analysis and interpretation of the data table, the curriculum and the teacher's enactment also missed opportunities to support students to make explicit connections between the *Secrets of the Snowy Owl* video and the Snowy Owl data table. Suhor (1984) defined transmediation as the "translation of content from one sign system to another" (p. 250). Siegel (2006) suggested that the process of moving across sign systems (video, data tables, written words, etc.) has the potential to produce new meanings. In other words, when learners read and interpret multimodal texts that present related information using different sign systems, they have the opportunity to make connections that can enhance their conceptual understanding. However, to productively engage in the process of transmediation, young students may need significant scaffolding. While the video introduced key ideas about Snowy Owl migration, such as that they breed in the frozen north and then migrate south during the winter months, and that some years see enormous increases in the numbers of migrating snowy owls, this information was not revisited and leveraged in the context of supporting students' sense-making about the data in the table. Transmediation may be particularly important for supporting deep science learning because any single representation only partially represents a phenomenon. In turn, supporting students to engage in the process of transmediation has become a primary focus for the design and redesign of interactive viewing and reading guides for the MLs project. For example, in all reading/viewing guides, we are now identifying opportunities for teachers to support students to make explicit connections across multimodal text such as the written word, videos, firsthand investigations, images, tables, and graphical displays to support this complex work of translating and building meaning across sign systems.

Finally, analysis of field notes, enactment transcripts, and student artifacts is that students might have benefitted from additional support in using data from the bird sightings data tables, both in the contexts of analyzing the Snowy Owl data table and the data tables for their Ornithology lab birds, to support their claims. Recall that only 6 of the 16 focal students provided numerical data from the table as evidence to support their responses as they completed their Migration Case studies. The varying responses or lack of responses provided by the other 10 focal students suggest the possibility that some students may not have understood the meaning of the prompt, "Use data to support your response." This has implications for the design of curriculum materials for both students and the teacher and suggests the need for increased support for students to understand the meaning of claim and evidence, to understand what counts as data in particular contexts, and to incorporate data into their written explanations.

Findings from student interviews. In this section, I describe findings from interviews conducted with focal students, which provided additional insights about students' perceptions of and learning with the Unit 3 texts. The portion of the interview specific to the Snowy Owl data table, addressed here, began by presenting students with a digital version of the data table. Focal students were asked the following question: (1) What does this data table show? Depending on the depth of student's responses, I followed with probing questions to probe student thinking. Follow-up questions included the following: (a) What kinds of information can you learn from this table? (b) How can you tell? (c) How does the table tell you that? (d) How is the data different across the two years?

Students' interview responses provided additional evidence that all 16 focal students were able to read and interpret information from the data table. Two of the focal students, however, merged their experiences viewing the video, *Secrets of the Snowy Owl,* which focused on tracking a particular Snowy Owl named Baltimore, and the information provided in the data table. These students reported that the data in the table provided information about sightings of Baltimore specifically. For example, Malik reported that the table "shows how many people have seen Baltimore…a snowy owl, in different places and years," but then went on to accurately identify patterns in the data. Raven described the data table similarly: "…It shows like how many people saw Baltimore in 2007 and 2016…not a lot of people saw Baltimore in 2007 and they saw the most in 2016." Raven's responses to follow-up questions, however, also revealed that she was able to read and interpret the data in the table. The cases of Malik and Raven are examples of the ways in which drawing on prior experiences can serve to hinder sense-making with text.

In addition to students' responses to the interview question specific to the Snowy Owl data table, two students shared additional, unprompted, information that provided additional evidence of student learning with respect to reading and interpreting the data tables for their Ornithology Lab birds, in the context of completing the Migration Case Study artifacts. For example, as Julia described the Snowy Owl data table during her interview, she made connections to the data she analyzed and interpreted in the table specific to sightings of the Mallard Duck and compared this data to the data in the Snowy Owl data table: "And my Mallard Duck, there was like only big numbers up here (at the top of the chart) and the rest of the small numbers were down here (at the bottom of the chart) like them (Snowy Owls)." This excerpt illustrates the ways in which Julia analyzed and interpreted the data in her Migration Case Study chart focused on the Mallard Duck, and also the way in which she was able to compare data across the charts.

In another example, when asking about a different text related to migration, Ellie transitioned the interview conversation to describe the migration patterns of the bird she explored, the Baltimore Oriole.

Ellie: They *do* migrate.

Interviewer: Your bird migrates? The Baltimore Oriole?

Ellie: Yeah, 'cause can we go to WeRead[9]?

Interviewer: Yeah. So, you're clicking on the Migration Case Study for your bird?

Ellie: Yeah, and if you go to the…what's it called?

Interviewer: The table.

Ellie: The table. And you look, it's not there in any of the winter. You don't see any Baltimore Orioles in October, November, January, February, or March, and those are all winter.

Interviewer: So, what does that mean to you?

Ellie: …they *do* migrate because they leave in the winter and there's no sightings…and then you see them here and the time you see them the most is May in our season right now.

This excerpt from Ellie's Unit 3 interview provides additional evidence about the ways in which she was able to use the data table to explain the migration patterns for her bird, the Baltimore Oriole. That both Ellie (a typically higher-performing reader) and Julia (a typically lower-performing reader) identified explicit connections between their whole-class reading and

[9] WeRead is the website where students accessed all digital versions of MLs texts from any device, at school or home.

interpretation of the Snowy Owl data table and their small group reading and interpretation of the data table of their Ornithology Lab bird, during their end-of-unit interviews, is particularly promising. Research suggests that when curriculum designs include multimodality, learners who experience significant success are often those who have been labeled as "struggling readers" or identified with learning disabilities (Siegel, 2006). Thus, strategically integrating multimodal resources and supporting students to read and interpret information in order to build knowledge within single and across multiple modes of representation, may have the potential to reposition learners who have typically struggled to make meaning with text.

Conclusion

The findings described in Part II of this chapter illustrate the ways in which the data table text, task, and enactment worked in interplay to create opportunities for and to support students' science and literacy learning. There appeared to be affordances associated with the design of the data table. In this case, the design of the data table and the teacher's enactment supported students to identify and describe patterns in the data within and across years, identify and describe data that was surprising or unexpected, to make calculations that supported analysis, and to use the data to make a claim supported by evidence. Recall that the data table was designed to connect to core ideas related to bird migration (e.g., migration is a behavioral trait that is both inherited and learned), provide information that connected to and built upon first-hand observations and other texts, provide opportunities to engage in the scientific practice of analyzing and interpreting data, and to motivate and serve as a scaffold for students to analyze the migration patterns of their selected Ornithology Lab bird. Most of these potential design affordances were leveraged by the teacher in the context of the enactment. Excerpts from transcripts of classroom discourse and students' written responses to questions about their

Ornithology Lab bird's data tables provide evidence of students' engagement in the scientific practices of analyzing and interpreting data and constructing explanations of phenomena.

Students' whole-class reading and interpretation of the Snowy Owl data table served as a scaffold for students' more independent data table analysis and interpretation focused on another bird. My findings suggest that when students later worked with a partner to analyze and interpret data related to their Ornithology Bird's migration patterns, most (12 of 16) focal students were able to read and interpret information from the data table; however, when asked to include evidence from the table to support their responses, only 6 of the focal students did so. This suggests that students may need additional scaffolding in order to use data as evidence to support a claim. This finding is not surprising, in that research suggests that analyzing, interpreting, and communicating data, as well as developing scientific explanations continues to challenge students into the middle grades as they learn to navigate and use scientific discourses (Moje et al., 2004).

Lemke (2004) argued that, in order to read, interpret, and produce science text in service of knowledge building and to engage in scientific practices, students must develop skills for interpreting multiple modes of representation. Additionally, the CCSS for ELA call for students to read and interpret multiple modes of information. Specific to students' literacy learning, my findings suggest that the students' experienced little trouble, when supported by the teacher, to make sense of the ideas in the data table, an important mode of representation in scientific disciplines.

Finally, I identified missed opportunities with respect to supporting students to engage in the process of transmediation. When learners read and interpret texts that present related information using different sign systems, they have the opportunity to make connections that can enhance their conceptual understanding. However, my findings indicate that opportunities to support students to make connections between the Snowy Owl data table and the video, *Secrets of the Snowy Owl*, in addition to other unit texts and experiences were not leveraged in the context of enactment. To support teachers' enactment of the curriculum and to engage students in making connections across texts to deepen learning, we are explicitly calling these types of connections in the redesign of interactive reading/viewing guides.

Epilogue

Across the grade three MLs units, one unique feature of Unit 3 was the inclusion of a set of supplemental books related to the topics addressed within the unit of instruction. These books were available for students to access both during science instruction and other times of the school day in the case study classroom. This set included eight books about birds, three of which were field guides designed for young readers and supplemented by additional books that the teacher identified and checked out from the school library. There were multiple copies of many of the books included in the set.

Although students' use of this set of supplemental books was not the focus of the analyses within this finding chapter, the focal students' and their teacher's responses to this set of books warrant attention and suggest implications for the design and use of literacy resources in the context of project-based science instruction. In the end-of-unit interviews with students, I displayed each of the supplemental books and asked the following questions: (1) Which, if any, of these books did you read? (2) When did you read book [X] (during science instruction or during another time of the day)?

While students indicated that they often read the supplemental books during science time, the books were also a popular choice during Drop Everything and Read (DEAR) time, which the teacher provided daily. Additionally, one focal student indicated that he read one of the books in his reading group. Based on data from the end-of-unit student interviews, I found that 13 of the 16 focal students read one or more of the supplemental books, 11 read two or more books, and 7 read four or more of the books. Of the three students who indicated that they did not read any of the supplemental books, one explained that this was due to the scarcity of the books: "No, because everybody started taking them…there was nothing left." Another student, who indicated that she only read one of the supplemental books, also noted their high demand: "I couldn't really get to read any of it…because a lot of people wanted to read it and there wasn't really any." These interview excerpts illustrate the popularity of this set of books within the case study classroom.

In my end-of-unit interview with the teacher, I also asked her to reflect on the students' use of the supplemental texts during science instruction and other times of the day. The following interview excerpt illustrates the teacher's reflections on the use of the supplemental texts both within and beyond the classroom:

> It doesn't surprise me, because I think that when we, as teachers, get excited about something or we introduce something that is very relevant to what they are learning and it makes sense to them, and it's kind of in a fun easy way, whether it's going through…the field guide book and they're able to find different birds and just read a little bit or see the pictures…and a kid can go home and talk to their parent about it and they're like "What?!" and then they take it home and they read it together… They *do* love to read nonfiction more than they like to read fiction. So, hugely beneficial. I had to say, "No, you can't. No, we're not getting those out today," which I don't know if I ever *really* did, but I had to say, "Okay, you've had that for a week. You *have* to give it up to somebody

else to read." …I mean, I had books sitting out all year. Do you think they were *running* to those books? No. But, when we brought out just those few books about the birds…there weren't enough to go around because they *all* wanted to read one of the books… the picture books, the field guides, the nonfiction – they can't get enough of it. They can't get enough of it. And even like the field guides, for some of them, there's no way they could read them, but they could look through and they could look at the pictures and they could find out information based on what we had already done in here.

The teacher's reflection in her end-of-unit interview illustrates the potential of including these books as supplements to the MLs PBL units and the ways in which the texts served to leverage student learning and interest. Observational research suggests that many children in the elementary grades spend little class time actually *reading* text (Brenner et al., 2009; Jeong et al., 2010), which is troubling because children's opportunities to read are associated with the development of foundational skills such as fluency, vocabulary, and comprehension (Anderson et al., 1988). What is promising about the third-graders' and their teacher's interview responses regarding their reading of the supplemental texts is not only that the students took advantage of multiple opportunities to read during the school day, but also their excitement about doing so. In the teacher's reflection, she noted that, in addition to reading the books during science and DEAR time, some students took the books home to read them with their parents. Additionally, at least one student attempted to take one of the books home secretly to learn more about his Ornithology Lab bird. For instance, during his interview, Leon shared, "I had one in my backpack, but…I had to like kind of put it back in the box. I didn't really ask. I just wanted to keep it a secret so I can just like learn more about the Eastern Screech Owls." Like the teacher noted, she had a variety of texts out and available for students to access all year, but they were not “running to those books,” like they did to the books about birds. Thus, it is possible that the project-based instructional context provided unique opportunities for engaging students in sustained reading of informational text within and beyond the classroom. Based on these findings, we are developing lists of supplemental texts and suggesting ways for teachers to incorporate them into their instruction during each of the MLs units.

CHAPTER VII: UNIT FOUR

How can we grow plants for food in our community?

The instructional context for this chapter is the fourth *Using Multiple Literacies in Project-based Learning (MLs)* unit of instruction focused on disciplinary core ideas related to plant traits and growth, weather and climate, and ecosystem dynamics. The unit is framed by the following driving question: *How can we grow plants for food in our community?* In the unit, students explore plant traits, growth, and development, and investigate the effects of different environmental factors on the growth and distribution of plants, including weather and climate, to figure out how to grow plants for food in their community. Throughout the unit, students have opportunities to read and interpret a variety of text types, such as graphical, procedural, video, historical fiction, and informational text.

In the first part of this chapter, I focus on the selection and enactment of a historical fiction text about George Washington Carver, *In the Garden with Dr. Carver* by Susan Grigsby, which tells the story of Dr. Carver teaching adults in a community, in the southern United States, how to better care for their crops and helping children create and sustain a school garden. The enactment of the interactive read aloud was supported by a researcher-designed interactive reading guide (Appendix G). In the second part of this chapter, I focus on the design and enactment of another text from this unit called *Ms. Ollie's Plant Investigation* (Appendix H), which was designed to extend students' firsthand investigation of environmental factors that affect plant growth.

The Unit of Instruction

In this section, I describe the progression of the PBL unit leading up to the interactive read aloud of the book, *In the Garden with Dr. Carver*, and the researcher-designed text, *Ms. Ollie's Plant Investigation*, in order to situate these text-reading events within the larger unit of instruction. Following the introduction of the unit driving question (*How can we grow plants for food in our community?*), students began the unit by making and sharing observations of different types of produce (e.g., potatoes, cabbage, apples, oranges, etc.) and predictions about how and where different plants for food grow. To motivate pursuit of the driving question and the idea of building a school or community garden, the students participated in an interactive read-aloud of the book, *City Green* by DyAnne DiSalvo-Ryan, about a young girl who helps build a community garden in her neighborhood. Students then read and interpreted a "growing map," designed for children, which illustrated the top growing states for a variety of fruits and vegetables and was paired with informational text about the growing conditions required by those plants.

In the next set of lessons, students selected the plants (from a selection of ten plants) that they would grow for their class garden and made and recorded close observations of the traits of their plants' seeds and compared them to the seeds of their classmates. After observing the seeds, students participated in a scaffolded scavenger hunt activity, in which they read and interpreted procedural, graphical, and numerical information on the seed packets for their plants to learn more about the needs of their plants and how to begin growing them. Based on the seed packet information, students went on a walk around their school to identify more and less ideal spots for growing their plants in a community garden, based on the features of the environment that could impact their plants' growth (e.g., soil, sun, shade, temperature, etc.).

The next set of lessons was designed to support students to plan and conduct an investigation of how certain environmental factors affect plant growth, in order for them to determine the best conditions in which to grow their own plants in their class garden. The teacher could choose to support students to conduct one or more of three investigation options, using mung beans: (a) how different amounts of sunlight affect plant growth; (b) how different amounts of water affect plant growth; and (c) how different types of soil affect plant growth. In the focal classroom, the teacher and students chose to collaboratively plan and conduct an investigation of how light affects the growth of plants. In addition, the teacher also set up a teacher-led investigation in the classroom to figure out how different types of soil (e.g., nutrient rich, sand, no soil) affect specific types of plant growth. In order to motivate and support the planning of this investigation, students participated in an interactive read-aloud of the trade book, *In the Garden with Dr. Carver*. After analyzing their investigation data and making claims, in order to extend their investigation, to build upon students' first-hand findings, and to provide information about how and why certain features of the environment affect plant growth, students participated in an interactive read-aloud of the researcher-designed text, *Ms. Ollie's Plant Investigation*.

PART I: In the Garden with Dr. Carver

In this section, I focus on the selection and use of the trade book, *In the Garden with Dr. Carver,* and the researcher-developed teaching guide, which was designed to support enactment. The text focuses on core ideas related to plant traits and ecosystem dynamics and was designed and placed within the curriculum to motivate students' engagement in the scientific practice of planning and carrying out an investigation. First, I describe the text and teaching guide, provide an overview of the design features of the text and task, and describe enactment. To address my research questions, I (a) describe the ways in which the placement and enactment of *In the Garden with Dr. Carver* and the design of the teaching guide and tasks supported students' science and literacy learning; and (b) identify modifications to the design of the teaching guide and task that might enhance students' science and literacy learning, in the context of project-based science instruction.

Literacy and science education researchers have investigated and argued for the strategic inclusion of trade books in investigation-based science instruction for students in the elementary grades (e.g., Ford, 2006; Morrison & Young, 2008; Morrow, Pressley, Smith, & Smith, 1997; Pappas, Varelas, Barry, & Rife, 2004). Careful selection and use of science-related trade books (including biographical, informational, and historical nonfiction genres) has the potential to motivate and facilitate first-hand investigations, provide science content, bolster students' background knowledge, and support students' engagement in a variety of scientific practices, such as asking testable questions, making observations, and analyzing data (Pappas et al., 2004). In addition, Farland (2006) found that when elementary-grades science instruction was supplemented with historical, nonfiction trade books, third-grade students demonstrated broader perceptions of the work of scientists, where science is conducted, and who conducts it.

Additionally, some evidence suggests that the inclusion of trade books in hands-on science instruction can enhance students' motivation and interest in science. In their investigation of three groups of third graders (hands-on science only, literature only, and combined literature/science), Morrow et al. (1997) found that third-graders in combined literature/science classrooms more frequently chose to read science on their own than did students in the other groups. The researchers also found that the majority of students in the combined literature/science group reported liking science, whereas the majority of students in the other groups reported that they did not like science.

Literacy and science education researchers, who focus on the inclusion of trade books in science instruction, emphasize the importance of using trade books as tools to support inquiry (Ford, 2006). Thus, there are important considerations for both selecting and enacting trade books in the context of elementary-grades science instruction. Young and Moss (2006) identified five essential considerations for selecting science-related trade books: (1) author authority, (2) content accuracy, (3) audience appropriateness, (4) literary features, and (5) visual appearance. Ford (2006) argued that, beyond attending to the features of the books themselves, the power of incorporating trade books into elementary-grades science instruction lies in their use as tools to support scientific inquiry as students read, participate in first-hand investigations, and engage in rich discussions about ideas in text. This suggests that teachers need support in order to select and enact trade books in the context of investigation-based science in ways that align to meaningful science and literacy learning goals, such as those outlined in the CCSS and NGSS. This body of literature informed the selection of the historical fiction trade book, *In the Garden with Dr. Carver*, and the development of the researcher-designed reading guide to support its enactment.

Selection of the Text and Design of the Reading Guide: In the Garden with Dr. Carver

The trade book, *In the Garden with Dr. Carver*, and reading guide were selected and designed to: (a) illustrate core ideas related to plants' traits and ecosystem dynamics; (b) provide information that connected to and built upon students' first-hand observations and prior knowledge; (c) illustrate the work of a practicing scientist; (d) provide opportunities for students to interpret and analyze multimodal information (e.g., written text and images); (e) engage students in discussing the ideas in the text (e.g., both science ideas and the author's use of rich-descriptive and figurative language); (f) motivate the collaborative planning and carrying out of an investigation based on environmental factors that affect plant growth, introduced and/or revisited in the book; and (g) feature a scientist who was a member of a racial minority group, underrepresented in the sciences.

In the Garden with Dr. Carver by Susan Grigsby is a historical fiction trade book written for children, which is a fictionalized account of true events. The book is told from the perspective of Sally, a young girl living in the southern United States in the early 1900s. In the book, Sally tells the story of "George Washington Carver, the famous plant scientist" coming to her small Alabama town to help the community enhance the productivity of their farms and to help the children create and cultivate a school garden. The book highlights multiple features of the environment that affect plant growth, such as soil quality and sunlight. At one point in the book, Dr. Carver invites the children at the school to closely observe two rosebushes, one that is growing well and one that is not, and to identify differences in the environmental conditions in which the two plants are growing. In another part of the book, Dr. Carver invites the children to identify features of the soil that are better or worse for growing plants, and then helps them to improve the soil so that it will support a garden to grow and thrive. These portions of the book provide opportunities for MLs students to make close observations of the book's vivid illustrations and to make predictions about how certain features of the environment might affect the growth of their own plants. In addition, the book includes engaging information, delivered through the use of rich language, drawing on literary devices such as imagery, similes and metaphors, which created opportunities for students to discuss both the author's use of language and the ideas in the text.

The interactive reading guide was designed to support the teacher's enactment of the interactive read aloud in order to engage students in reading, interpreting, and discussing the ideas in the book. The interactive reading guide included suggestions for ways in which the teacher could leverage the content of the book in order to motivate students' collaborative design and conduct of their own first-hand investigation of variables that affect plant growth, and to support students to generate and focus on testable questions (e.g., "Your students will notice that the rose bush that is growing poorly, does not receive sunlight, while the other bush does. You may record this as one environmental condition students might investigate using the mung beans: *How does the amount of light affect how mung beans grow?*"). In addition, the interactive reading guide was designed to support the teacher to engage students in discussing the ideas in the text and in analyzing the author's use of language (e.g., "You might ask why Dr. Carver compared cotton to 'a hungry monster' and what problem he wanted to solve."), as well as to connect to students' prior knowledge and experiences in the unit of instruction (e.g., "The students can discuss what Dr. Carver meant when he said to Sally, 'Listen to the plants and they will tell you what they need.' The students can then discuss ways in which they have been 'listening to plants' as they observe their seeds growing.").

Overview of Enactment

Prior to reading the book, *In the Garden with Dr. Carver*, the teacher made connections to students' prior learning and experiences in the unit by revisiting the previous day's task of exploring the area around the school to identify locations that the students thought either would or would not support their plants to grow well. Students briefly summarized their observations and identified the features of the environment that they thought would best support their plants to grow well, such as grass, shade, and sunlight. Students also identified features that they thought would not support their plants to grow well. After revisiting these ideas, the teacher introduced the book, connected to the unit driving question, and engaged students in an interactive read aloud. Following the book reading, the teacher enlisted students in collaboratively planning an investigation, which students would conduct over the next few weeks of instruction, to determine for themselves how certain environmental variables affect plants' traits and growth.

Table 7.1

In the Garden with Dr. Carver and Planning Investigation Enactment Timeline

Lesson	Day	Lesson Activities
How can we test how the environment affects the traits of our plants?	Day 1 55 mins.	• Teacher and students revisit previous day's task of identifying locations around their school that might best support their plants to grow well and why • Teacher introduces book and engages students in interactive read aloud of *In the Garden with Dr. Carver* • Teacher introduces the task of collaboratively planning their own investigation of how environmental variables affect plant growth • Teacher supports students to collaboratively plan a fair test to investigate how the amount of light affects mung beans' growth and physical traits

Testing Conjectures

In analyzing and reporting data specific to the selection and enactment of *In the Garden with Dr. Carver* and investigation planning task, I foreground the following features of the designed MLs learning environment (i.e., *embodiment*): (a) the designed tools and materials, including teacher supports (i.e., lesson plans, interactive reading guide) and multimodal literacy resources (i.e., text); and (b) the task structure. The mediating processes outlined in my conjecture map served as analytic lenses, guiding my analyses of enactment data, artifacts, and interviews. For instance, to understand whether and how mediating processes produced desired outcomes within the lesson, I drew on transcript, class-generated artifact, (i.e., record of investigation plan), and interview data in order to closely analyze the ways in which these mediating processes emerged and unfolded in the classroom.

The close analysis of transcribed video of lesson enactment and interviews allowed me to analyze the ways in which the designed tools and materials (e.g., teacher supports, literacy resources) and task structure produced observable interactions: (a) using tools of reading, writing, viewing, and discussing for meaningful purposes, (b) using scientific ideas and practices, (c) building on prior knowledge and funds of knowledge, and (d) the teacher's instructional moves. Analyzing observable interactions revealed within the transcript data in combination with class-generated artifacts and interviews, allowed me to examine whether and how mediating processes led to desired outcomes, including (a) making sense of and synthesizing multimodal texts and (b) using science ideas and practices to make sense of and explain phenomena. I present my findings in the following section.

Findings

In this section, I present findings from my analyses of enactment data (lesson plans, field notes, and transcribed video recordings) and interview data with focal students to respond to my research questions: (1) How did the design of the placement and enactment of *In the Garden with Dr. Carver* and the design of the teaching guide and tasks support students' science and literacy learning? (2) How might modifications to the text and task better support third-graders' science and literacy learning, in the context of project-based science instruction?

Findings from enactment. I found that the selection of the trade book, *In the Garden with Dr. Carver*, and the design of the reading guide and task synergistically supported third graders' science and literacy learning. I also identified missed opportunities, both within the design of the curriculum resources and the enactment of the lessons, for further supporting the science and literacy learning of all students.

Before reading: Connecting to prior knowledge and preparing to read. Analyses of the written curriculum and transcripts of classroom enactment revealed that the teacher leveraged the text, the teaching guide, and the task in support of students' science and literacy learning by supporting students to connect to their prior knowledge and experiences in the unit, and (2) making predictions prior to reading.

Reviewing prior unit experiences. One way that the teacher supported student learning prior to reading the text was by making connections to students' prior knowledge and experiences, and then drawing connections between students' previous unit experiences and the content of the trade book. Recall that activating students' prior knowledge and experiences, as well as making connections to the unit driving question before reading, was a common feature of enactment across units. In addition to evidence that activating prior knowledge supports strategic reading and comprehension (e.g., Brown et al., 1996), some research suggests that explicitly connecting lessons, activities, and big ideas during enactment may be particularly important for supporting student learning during inquiry-based instruction, such as PBL. For instance, Puntambekar, Stylianou, and Goldstein's (2007) findings from their investigation of differential classroom enactments of an inquiry curriculum illustrated the importance of teacher moves that supported students to understand how unit activities were connected to one another and to the big ideas of the unit for driving student learning in inquiry-based learning contexts.

Prior to beginning the interactive read aloud of the trade book, *In the Garden with Dr. Carver*, the teacher launched the lesson by asking students to recall and share what they did in science during the previous day's instruction and connected to the unit driving question.

Teacher: What did we do yesterday, during science? …Ellie, what did we do?

Ellie: We went out to the perimeter of our school and we looked around and we talked about places where would be good to plant our seeds and where it wouldn't be good to plant our seeds and when we got back to the school, we wrote down, we drew a picture and wrote down why or why not it was a good place to plant it.

Teacher: Okay, and what were some of those reasons why it may have been a good spot or it may not have been a good spot? What were some of the things we were looking for? Keyanta?

Keyanta: We were looking for like places to plant, like at the ground…but, I think the grass because…you usually see spinach (Keyanta's plant) growing in the grass.

Teacher: Certainly, we were looking for places on the ground that we thought would be good places to plant our seeds, right? What specifically may have made something a good spot or it may not have been a good spot, Nick…?

Nick: Because the lima beans (Nick's plan), we needed shade and sun.

Teacher: Okay, so for some of your seeds, you needed both shade and sunlight, alright? Ellie?

Ellie: Well, I know a place that it isn't so good. Out in the field because like when we were walking out of there we saw a frog and there might be other wildlife like squirrels and chipmunks and they might…if you put it out in the open, they would still have a good touch to get the food and eat it and then you won't have it anymore.

Teacher: Good senses to find it, okay. Alright, excellent. So, this is a book we're reading. Obviously, we're talking about planting. We're talking about things that plants need…

Students: To survive!

Teacher: …what helps plants grow up and thrive.

Student: And thrive!

Teacher: We're growing food for our community, right?

This excerpt illustrates the way in which the teacher supported students to make connections to and summarize the previous day's activities, which included going outside to make observations and identify locations around the school that students thought either would or would not provide optimal environmental conditions to support their plant's growth. At the beginning of the excerpt, the teacher asked Ellie to describe what they did. After providing a summary of the activity, the teacher pressed for elaboration from other students regarding specific reasons they thought certain locations provided good or bad growing conditions, to which students responded with ideas such as shade and sunlight. Finally, the teacher transitioned the conversation to introducing the trade book by saying "…this is a book we're reading. Obviously, we're talking about planting. We're talking about things that plants need…" and made a connection to the unit driving question (i.e., "We're growing plants for our community, right?").

Connecting to prior knowledge and making predictions. After the teacher supported students to connect to the driving question, prior unit learning, and the previous day's activities in order to introduce the book, she also engaged students in sharing prior knowledge about

George Washington Carver and in using their prior knowledge to make predictions before reading.

Teacher: So, *In the Garden with Dr. Carver*. Anyone have any idea who they think this Dr. Carve may be? Makayla?

Makayla: George Washington Carver.

Teacher: George Washington Carver. Why do you think that this may be George Washington Carver? You're correct.

Keyanta: I have a book about him!

Teacher: You have a book about him? Okay…Why do you think Dr. Carver might be in a book about *In the Garden with Dr. Carver*?

Lucas: Because he plants. Because he's famous for plants.

Student: His planting!

Teacher: He is. He is very well known for what he learned and what he discovered with planting. Is there a specific plant? I think he had over 300…

Student: Lima beans.

Student: Peanuts.

Teacher: Peanuts. Yep, absolutely…and it was significant because...what was Dr. Carver born into? What was he born into?

Student: A slave.

Teacher: He was born a slave, alright. He was born a slave.

In this brief excerpt, in which the teacher introduced the trade book, the teacher elicited students' prior knowledge about George Washington Carver and asked students to connect this knowledge to the purpose for reading the book and to make predictions about the content of the book. For example, when the teacher why George Washington Carver might be in a book entitled, *In the Garden with Dr. Carver*, Lucas shared that it is "because he plants. Because he's famous for plants." As the conversation continued, other students shared knowledge about Dr. Carver as well, including his work with peanuts and that he was born into slavery.

During reading: Supporting students to read and interpret multiple modes. Analyses of the written curriculum (e.g., text, lesson plan, reading guide) and transcripts of classroom enactment revealed that the teacher leveraged the text, reading guide, and task in support of students' science and literacy learning by supporting students to read and interpret the written text and illustrations in the trade book. During the interactive read aloud for *In the Garden with Dr. Carver*, the teacher leveraged the reading guide to elicit students' ideas and support reading and interpretation by (1) engaging students in making predictions and discussing ideas in the text, particularly in the context of analyzing illustrations, which would later inform their planning of a first-hand investigation; and (2) connecting to students' first-hand experiences. In addition, students identified intertextual connections to texts read earlier in the unit of instruction and in previous units of instruction, while reading the trade book.

Analyzing print and visual information. Recall that, in part, the *Dr. Carver* trade book was selected and the reading guide was designed in order to provide opportunities for students to analyze multimodal information (e.g., written text and illustrations), to engage students in discussing ideas in the text, and to motivate the collaborative planning of an investigation based on environmental factors that affect plant grow (e.g., amount of sunlight, type of soil). I found that, during the interactive read aloud, the teacher leveraged suggestions in the teaching guide to engage students in this work. In this section, I present two examples, selected because of their relationship to the task of planning and conducting the first-hand investigation that followed.

One suggestion included in the interactive reading guide, read as follows: "At this point in the text, you can encourage your students to look closely at the two rose bushes and observe what is different about where they are growing." This suggestion was included in the guide in order to engage students in carefully observing the differences in the environmental conditions in which multiple plants were growing, as well as the differences in those plants' traits. Based on this suggestion, the teacher engaged her students in extended discussion of both the print text and the illustrations on this set of pages in the book. Recall that the illustration depicted a scene in which a very small rosebush with a single flower was growing in the shade of a building that was blocked from the sunlight (bottom left of page), and a row of large, full rosebushes with many blooms that were growing along a wooden fence in full sunlight (bottom right of page), with the children and Dr. Carver looking closely at the plants. After reading the first sentence on this page of the book aloud (*But for me, the best part of Dr. Carver's visit was that he agreed to stay through Monday to help us with the garden at our school.*), the teacher invited students to make predictions, based on the written text and illustrations.

Teacher: Before I read any more, any predictions on what you think they might need help with, based on this picture…Rachel?

Rachel: Helping keep the soil healthy.

Teacher: Okay, helping keep the soil healthy. Kaylee?

Kaylee: Maybe getting rid of the plants that were eating all of the soil.

Teacher: Getting rid of the plants that were eating all of the soil.

Student: Cotton.

Teacher: Okay. Lucas? Look specifically at the picture.

Lucas: To help grow a tree.

Cameron: To help grow plants.

Teacher: Any specific kind of plant?

Student: Roses.

This brief excerpt illustrates the way in which the teacher engaged students in making predictions about what the children in the book might need help with based on the illustration. This initial portion of the discussion focused on defining the problem – that the children in the book needed help growing plants, and specifically roses.

As the discussion continued, the teacher invited students to elaborate on their observations of the illustrations and to connect to related prior knowledge, in order to make additional predictions. After predicting (above) that the children in the book might need help growing the roses in the illustration, the teacher then asks students to predict what Dr. Carver might suggest to the children in order to help their roses grow.

Teacher: Based on what you're seeing in this picture, what do you think, just based on what you know, and before I read any more? Any predictions on what you think Dr. Carver might suggest? Any suggestions that he might have I heard somebody say – about helping the roses grow?

Student: Pick up the litter.

Teacher: Okay, I don't see too much litter around there, but certainly having a healthy environment helps. Lucas?

Lucas: Kill all the weeds that are around there because it will take up all the stuff because there's all the weeds right there, a weed right there, and a weed right there (*Standing up to point at each of the dandelions in the illustration*).

Teacher: Okay, so what do you notice is growing well?

Student: The roses.

Student: The flowers.

Teacher: Okay, which roses, where are they?

Ellie: By the fence.

Teacher: Okay, so the roses by the fence are growing well.

Ellie: Okay, so do you see the difference between where they're located?

Students: Yeah!

Kaylee: One's in the shade, and the ones in the sun look healthier but the one in the shade looks very not healthy because it's not getting all the nutrient sit needs.

Ellie: It doesn't get all the sunlight.

The teacher began this exchange by asking students to make predictions about what Dr. Carver might suggest for helping the roses grow. Several students made predictions, some which clearly reflected portions of the illustration (e.g., kill all the weeds) and others which did not (e.g., pick up the litter). The teacher prompted students to focus specifically on the roses and to describe the differences in their locations. At this point, Kaylee introduced the idea that the rose bush that was growing in the shade was not growing as well as the rose bushes that were growing in the sunlight, which Ellie echoed.

The teacher then read the next portion of the text on the page in which Dr. Carver talked with Sally about the condition of the roses: "…why do you think that this rosebush is looking so weak, when her cousins by the fence are covered in beautiful red roses?... Listen to the plants, and they'll tell you what they need. Go on." After reading this portion of the text, the teacher asked the students if plants can tell us what they need and, if so, what the rose bushes in the illustration were telling them.

Teacher: Can plants tell you what they need?

Students: Yes.

Teacher: I would agree with that statement. What are those rose bushes telling you along the fence?

Ellie: I'm healthy!

Teacher: Makayla, what are they telling you?

Makayla: That they're healthy.

Teacher: That they're healthy. How do you know that they're healthy?

Cameron: Because they're blooming.

Teacher: Okay, they're blooming. So, what do you think they're telling you that they need? Zayn?

Zayn: The ones in sun are saying they're getting all the sun and stuff because they're getting everything they need, and the rosebush in the shade gets everything but not the sun, so…

Teacher: Okay, so they're certainly saying, "We really like where we are. We're growing, we're thriving, we're looking beautiful." Do you think that there's anything else that could be different about what they're getting?

This excerpt further illustrates the ways in which the teacher leveraged the suggestion from the teaching guide to engage students in discussing ideas in the written text and illustrations. It also illustrates one way in which trade books can be used to facilitate students' observing, analyzing, and questioning (Pappas et al., 2004). For instance, after Dr. Carver's character introduced the idea that plants will "tell you what they need," the teacher posed this as a question to the class and invited students to describe what the rose bushes in the illustration were telling them. After identifying that the different rose bushes were receiving different amounts of sunlight, the class considered whether any other features of the environment in the two locations might differ (e.g., air or temperature). As the teacher continued reading the following pages, Sally's character also came to the conclusion that the rose bush in the shade needed more sunlight, like the roses growing along the fence.

Several pages later, the teacher leveraged another suggestion from the reading guide to engage students in a similar discussion. In this example, the reading guide suggested the following: "Dr. Carver and the children in the book consider a location, with dry, rocky soil to plant a garden. Here, you might ask students again what environmental condition this suggests they might investigate…" While the teacher did not connect the discussion about the written text and illustrations on this page explicitly to planning the first-hand investigation (which she had not yet introduced), she *did* again engage students in making and sharing observations and ideas. After reading aloud the first two sentences on the page (*...Dr. Carver said that it was time to plant our own kitchen garden. We followed him to the lot behind our school.*), the teacher invited students to share what they noticed about the land in the illustration.

Teacher: What do you notice about it?

Lucas: It's clean.

Student: It looks hilly...

Aiden: It looks like it's lonely and flat.

Carter: A perfect spot to grow plants!

Aiden: It looks sad and lonely…

Cameron: It looks like a big field.

After gathering a range of students' initial observations, the teacher continued reading (*"This spot is no good," Emmett said. "It's sunny, but the soil's rock-hard…" "He's right," I said, "Nothing ever grows out here, not even weeds." "And nothing ever will, unless we improve this worn-out land," said Dr. Carver...)*, and then invited students to share ideas about what the children in the book might do to improve the land.

Teacher: Any thoughts as to what they could do to turn that into a place where they could grow plants? Because right now, not even the weeds are growing, and I'm sure your parents who have to do the yard work, talk all the time about the weeds…but those won't even grow there? Any thoughts?

Jeremiah: Water.

Teacher: Jay, what do you think they could do?

Jeremiah: Water it.

Teacher: What would putting water on that do?

Jeremiah: It would make it not so hard.

Teacher: Okay, it would soften it, you are saying.

This excerpt provides a brief snapshot of the way in which the teacher invited students to share ideas about what the children in the book could do to improve the land where they hoped to plant their garden. Jeremiah suggested that they children could water the land to "make it not so hard." As the conversation continued, other students built on Jeremiah's suggestion, proposing that the land might need *a lot* of water and also that the children in the book might need to flatten the land or put "fresh soil" on top of the land in order to successfully grow plants there.

Connecting to first-hand experiences. In addition to supporting students to read, interpret, and discuss the written text and illustrations in the book by leveraging the suggestions in the teaching guide, the teacher also leveraged opportunities to connect to students' firsthand experiences beyond the unit of instruction. Earlier in the week, students had planted flowers as Mother's Day gifts. When reading, viewing, and discussing the portion of the book in which Dr. Carver and the children talked about the condition of the land and ways to improve the land in order to plant a successful garden, the teacher supported students to connect to their own experiences using soil to plant flowers.

Teacher: How many of you, when you help someone plant this weekend, or when you planted flowers for your mom, had to break up big chunks of dirt? (*Many students raise their hands.*) If we didn't break that up, if that sat in the bag over time, what do you think would happen to that? What would happen to that soil that we broke up?

Cameron: It would be so dry.

Teacher: It would become very dry wouldn't it?

Cameron: It would become very dry.

Teacher: If the soil becomes very dry, it becomes very what?

Students: Rocky.

Teacher: Rocky or hard…

Ellie: And then the plants don't grow.

In this example, as the teacher read aloud about the land in the book, she paused to connect to a firsthand experience shared by all students in the class in order to illustrate the way in which the land was described in the book (e.g., rock-hard). Connecting to shared prior knowledge provided opportunities for students to further visualize the soil described in the book, by reflecting on their own experiences with using soil for planting.

Identifying intertextual connections. During reading, students identified and shared two notable intertextual connections to other books that the class had read earlier in this unit of instruction (*City Green* by DyAnne DiSalvo-Ryan) as well as in earlier *MLs* units (*From Water Squirter to Super Soaker*, Unit 2). In the first example, after reading the first page of *In the Garden with Dr. Carver,* Ellie identified a connection to Lonnie Johnson, featured in the researcher-designed text, *From Water Squirter to Super Soaker*.

Teacher: (*reading aloud*) "…The man with the wagon was George Washington Carver, the famous plant scientists from the big school in Tuskegee."

Ellie: Isn't that where Lonnie Johnson made his toy?

Teacher: Yes, it is the same school that Lonnie Johnson went to and it's in Alabama, I'm pretty sure.

Student: Yeah, it's in Alabama.

While this exchange was brief, it is notable that Ellie identified this cross-text connection, as it suggests that she was integrating new information with prior knowledge, in this context. The connection was also highlighted in the interactive reading guide, but Ellie introduced it before the teacher had an opportunity to do so.

In another example of students identifying cross-text connections, in the context of reading, analyzing illustrations, and discussing the portion of *Dr. Carver* related to improving the soil to plant a garden, Kaylee made a connection to the book, *City Green*, in which a young girl works with others in her neighborhood to clean up an abandoned lot to plant a community garden.

Teacher: Any thoughts as to what they could do to turn that into a place where they could grow plants? Because right no, not even the weeds are growing… (*several turns of talk*) Kaylee?

Kaylee: Just like maybe there like was a building there. Maybe, well, I remember how that girl said, "Let's build a garden there," and maybe that will happen like the same thing.

Teacher: Okay, so you're remembering *City Green*. You're making that connection and you're saying that they actually turned, where there used to be an old building, into a garden.

This example illustrates the connection Kaylee identified regarding the similar problem faced by the characters in *Dr. Carver* and *City Green*, in which a piece of land had to be cleared and improved in order for characters to plant a successful garden.

After reading: Planning a firsthand investigation using fair tests. Analyses of the written curriculum and transcripts of classroom enactment revealed that the teacher leveraged the lesson plan, reading guide, and task in support of students' science and literacy learning by supporting students to plan a firsthand investigation after reading *In the Garden with Dr. Carver*. Following the interactive read aloud, the teacher (1) introduced the task of planning an investigation, (2) supported students to summarize prior knowledge and experiences, and (3) engaged students in co-constructing an investigation plan specific to conducting fair tests.

Introducing the investigation task. Immediately after reading and discussing the ideas in the text, the teacher transitioned to introducing the plant investigation that students would collaboratively plan and conduct. Recall that planning and carrying out investigations are important scientific practices. NGSS calls for students in the elementary grades to plan and conduct goal-driven investigations in which they predict outcomes and design investigations that will produce data to provide evidence, which students may use to support their claims about phenomena (NGSS Lead States, 2013, Appendix F). This lesson was designed such that ideas for planning and conducting the investigation were seeded in the *Dr. Carver* trade book, and identified in the interactive reading guide as opportunities for motivating the investigation (e.g., "You may record this [sunlight] as one environmental condition students might investigate using the mung beans."). While the teacher did not introduce the investigation, and record these ideas during the interactive read-aloud, she did so immediately following the reading:

> So, let's continue to be botanists and scientists ourselves, and let's think about, if we wanted to do an experiment, and test things that we think we already know, and we wanted to know what plants needed, how do you think we could go about…investigating what you think plants actually need …? What are the things that we've talked about knowing that plants actually need?

Recall that, while students had generated many ideas about what they thought plants need to grow well, the *Dr. Carver* book emphasized certain needs, which the class discussed at length during reading, including sunlight and rich soil. Here, instead of directly linking to the book or asking students to recount the needs of plants that were described in the text and represented in the illustrations, the teacher asked students to share, more generally, their current thinking about what plants need to grow well. Since students had just participated in the interactive read aloud in which plants' needs were emphasized, it is likely that they drew from these experiences in the recounting of plants' needs that followed.

Summarizing prior knowledge and experiences. After introducing the idea of planning an investigation to figure out "what plants need," the teacher invited students to share their current thinking about what plants need to grow well. Throughout this discussion, students shared and the teacher recorded many of the needs that were addressed in the *Dr. Carver* book.

Teacher: What are the things that we've talked about knowing that plants actually need…Makayla?

Makayla: Water.

Teacher: Okay, so we know… (writing "Water" on the chart paper) …Benny?

Benny: Soil.

Teacher: (Writes "soil" on the chart paper) Zayn?

Zayn: Sun.

Teacher: Can we say sunlight (recording on chart paper) …?

Carter: They need roots.

Teacher: Okay, well, they eventually get the roots and you're right, they do need those, but to start growing, what do they need?

This brief excerpt illustrates the way in which the teacher engaged students in reviewing their current thinking about plants' needs. Students introduced ideas such as water, soil, sun, and roots. When Carter suggested that plants need roots, the teacher clarified that she was asking about what plants need to grow, not parts of the plants, even though these are also essential to survival. As the conversation continued, students proposed additional ideas, such as worms, shade, and oxygen, and the teacher continued to record students' ideas on the chart paper (see Figure 7.1).

Co-constructing an investigation plan. After collecting and recording students' ideas about what plants need from the environment in order to grow, the teacher referenced the interactive reading guide and engaged students in the work of collaboratively planning the first-hand investigation. This process began with determining how to conduct a fair test.

Teacher: (*Looking at the interactive reading guide*) So, what if we wanted to figure, because a lot of you say sunlight and shade, alright? If we wanted to test if plants really need this in order to grow, how could we conduct an experiment? (*Looking back at interactive reading guide*) Zayn?

Zayn: Maybe…write down somewhere where you want to put them, and then put them where it is and then…sun or shade.

Teacher: So, you're sticking with light… You're sticking with how much light they need…? Okay, so let's talk about that. What if we wanted to test to see how much light plants need or how light affects how plants grow, alright? How could we go about doing that? What would we have to do? Think about everything you know about experiments and how to conduct experiments. What would we have to do? …Lucas?

Lucas: You would have to do a test fairly?

Teacher: We'd have to do a fair test, okay. So, what does that mean, a fair test?

Lucas: Equal.

Teacher: What does that mean, a fair test? Nick, what do you think that means?

Nick: Like, let's say that…it's a fair test if you have the same exact thing, like…let's say two people were taking a test and someone had to…and someone got the answer key and someone didn't.

Teacher: Okay, so that wouldn't be a fair test, right, to know what people know if someone had the answer key and someone didn't…So, let's say if we wanted to test how light affects plants and we wanted to do a fair test, you're saying that some things need to be the same and some things need to be different. What would need to be the same? What would we need to keep…Ellie?

Ellie: I know something that we could do for light. We could plant two of the same plants…and we would put one in the shade and the one in the shade, you would water it and for the sun, you wouldn't. That *wouldn't* be a fair test if you do that.

Teacher: Okay, so you're saying that if we did the same plant – and I'm going to tell you, we're going to do this – and we're going to use something called mung beans…So, we're going to keep the same plant and…Ellie's right, the thing that's going to be the same is the seeds that we're going to plant.

Ellie: But we're going to put them in different places.

Teacher: But we're going to do one that has full sunlight, we're going to give one some shade, and what if we wanted to do a third experiment?

This excerpt illustrates the ways in which the teacher leveraged the suggestions in the interactive reading guide to launch students' initial investigation planning, including identifying the variable (e.g., amount of light) students would investigate and brainstorming how they could design a fair test. For instance, the reading guide suggested, "One way that you may use this book with your students is to support their initial brainstorming/planning of their mung bean investigations… You may record this (sunlight) as one environmental condition students might investigate using the mung beans." At the beginning of this excerpt, the teacher focused on students' ideas related to sunlight and shade – ideas that were seeded in the *Dr. Carver* trade book – and engaged students in proposing ways in which the class could investigate how the amount of sunlight affects plant growth (e.g., “A lot of you say sunlight and shade…What if we wanted to test to see how much light plants need to grow…how could we go about doing that?”). After the first exchanges, Lucas introduced the idea of conducting a fair test. Recall that the idea of fair tests was a primary focus during the enactment of *The Balloon Rocket Story* and investigation, reported on in Chapter 5 of this dissertation study. As this excerpt continued, the teacher and students discussed examples of fair and unfair tests, and then introduced the idea of placing the mung beans in different light conditions to conduct the investigation.

As this lesson progressed, the teacher continued to lead whole-class and small-group discussions with students, scaffolding their collaborative investigation planning, using fair tests. This included coming to consensus about the three light conditions in which the class would place the plants (e.g., full light, partial light, no light) and determining locations in the classroom that would best provide those environmental conditions. For instance, the class determined that they would place the plants growing in “full light” in the window, the plants growing in “partial light” under the teacher’s desk, and the plants growing in “no light” in a dark closet in the classroom (Figure 7.1). Additionally, students worked together to co-construct the variables that they would need to control or keep the “same” (e.g., air, temperature, amount of water, type and amount of soil, space, etc.), in order to ensure that the investigation they planned would be a fair test. Through the co-construction process, students’ ideas were shared and made public, recorded by the teacher on chart paper.

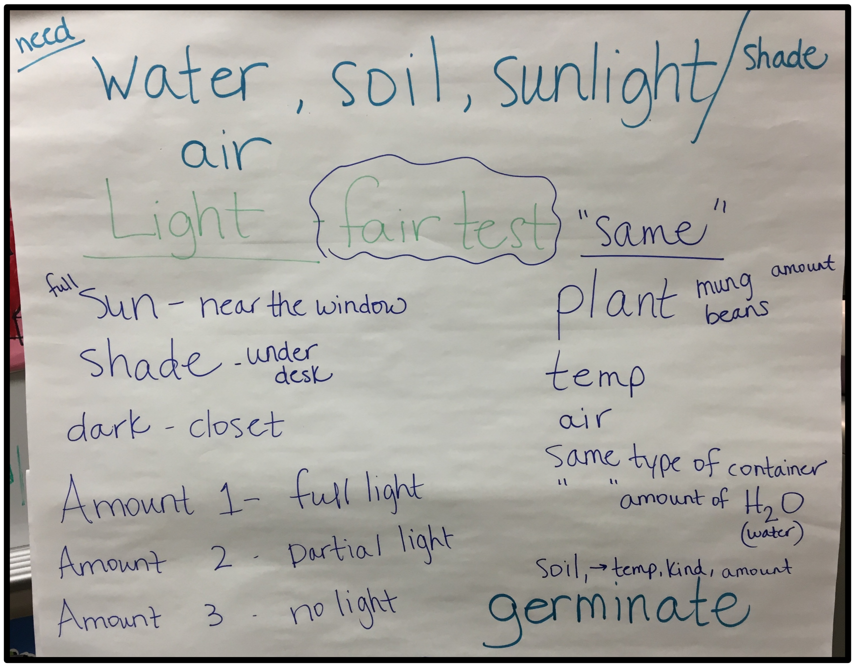


Figure 7.1. Class notes for planning a fair test to investigate how amount of light affects a mung bean plant's growth.

Constraints of the text and task revealed through enactment. In addition to the affordances of the written curriculum and its enactment, my analyses also revealed constraints related to the design of the text and task, and the teacher's enactment, which has implications for design revisions. Analyses of transcripts from classroom enactment, in hand with the interactive reading guide, revealed that while the teacher leveraged reading guide suggestions, the majority of the suggestions provided were not incorporated into the enactment of the *Dr. Carver* text. This was particularly the case for those suggestions related to supporting students to analyze and interpret the literary elements of the book.

Young and Moss (2008) identified literary artistry as an essential consideration for selecting and incorporating trade books into inquiry science instruction. Written in narrative form, *In the Garden with Dr. Carver* included many features that reflected literary artistry, such as the use of figurative language, including metaphors, similes, and personification. Recall that, in addition to addressing the NGSS, this design-based research is committed to addressing select

CCSS for ELA, which include standards for analyzing text craft and structure (e.g., RL.3.4 Determine the meaning of words and phrases as they are used in a text, distinguishing literal from nonliteral language.). Addressing this aim, and because the book provided many rich opportunities for students to interpret nonliteral and literal phrases, several suggestions were included in the reading guide to support this work (see Table 7.2 for examples). However, observations indicated that the teacher did not incorporate any of these suggestions during instruction.

Table 7.2

Interactive Reading Guide Excerpts

Examples
Text: **The adults all gathered around, eager for advice…** You might ask why Dr. Carver compared cotton to "a hungry monster" and what problem he wanted to solve?
Text: **He was even teaching…** After reading this paragraph, discuss what the author means when she writes, "he (Dr. Carver) was even teaching people how to turn simple foods like peanuts and sweet potatoes into luxuries like coffee, butter, and sugar." [The author is not being literal in this case…rather, the author is pointing out that Dr. Carver figured out how to use the plants that farmers could grow on their lands to make many products which could then be sold. From the money farmers got from these sales, they could buy luxuries like coffee, butter, and sugar.]
Text: **A plant is a weed if it's growing uninvited…** Before reading this part of the text, the students can talk about their own definitions for the word, "weed." Collect a few definitions and then read Dr. Carver's definition: "a weed is a plant that is growing but has not been invited." The students can compare this interesting definition of a weed with their own definitions.
Text: **After our feast, Dr. Carver said…** The class can discuss what Dr. Carver meant when he said, "Nothing ever will (grow in the land behind the school), unless we improve this worn-out land. Plants, like people, need nutritious food to help them grow."

There are a number of possible reasons that the teacher may have decided not to incorporate these suggestions into the interactive read aloud of the *Dr. Carver* text. One likely reason is the limited time the teacher had available to dedicate to science each day. In other words, the teacher may have chosen to prioritize the suggestions that were most clearly tied to the science ideas in the unit and the investigation that students would plan following the reading. Including the many additional prompts would have required the commitment of substantially more time to reading and discussing the ideas in the text. A second possibility is that the teacher made a conscious decision to focus exclusively on the portions of the reading guide that were specific to supporting students' knowledge building, observations, and discussions that would leverage their participation in collaboratively planning their own plant investigation that followed. A final possible reason for excluding many of the suggested prompts into enactment is related to constrains within the design of the reading guide. For example, the teacher committed the most attention and time to the first two prompts on the reading guide that suggested students closely observe and discuss the ideas in the text and illustrations related to the ways in which sunlight and soil quality affect plants' growth. The other suggested prompts followed, beginning on page two of the guide. In addition, while each prompt on the guide was introduced by signaling the first sentence of the page to which the suggestion referred, it is possible that, without page numbers, it was simply too difficult for the teacher to tack back and forth between the guide and the corresponding pages in the book as she led the interactive read aloud (i.e., the pages in the trade book are not numbered).

These findings suggest a number of possible changes that might enhance teachers' uptake of the variety of suggestions included in the interactive reading guide. It is possible that enacting these suggestions might have been more compelling to the teacher had the design explicitly signaled the CCSS ELA standards connections afforded by leveraging the suggestions. It is also possible that, if standards connections were signaled, even if the teacher had limited time to commit to reading and interpreting the text during science instruction, the argument for considering use of the text during ELA time might be more compelling. Additionally, adding suggestions to the guide regarding strategies for tacking between the suggested prompts in the reading guide while reading aloud, such as placing sticky notes to mark pages that mapped to particular suggestions, might have made the process of keeping track of the ideas in the guide more manageable.

Findings from student interviews. In this section, I describe findings from interviews conducted with focal students, which provided additional insights about students' perceptions of and learning with Unit 4 texts. The portion of the interview protocol addressed here, consisted of a subset of questions from the larger protocol, which addressed all texts from the unit of instruction.

The interview began by showing students all texts from the unit that were enacted as a whole-class interactive read alouds (i.e., a total of six texts for Unit 4). The students were then asked: (1) which text they learned the most from, what they recalled about the text, how it was helpful to their learning, and if there were any changes the curriculum designers should make to the text in order to make it more helpful; (2) which text was the most interesting and what was interesting about it; (3) if their teacher were only able to keep one of the texts to use with her students next year, which she should keep and why; and (4) if their teacher should skip any of the texts next year when teaching the unit and why. Students were told that they could select the same text for multiple questions, if they chose to do so (e.g., a student could identify a text as most interesting and as the text that they learned the most from). Additionally, due to students' protests regarding having to select only one text in response to each interview question, each focal student was invited to select and describe a first *and* second choice per interview question.

Specific to the trade book, *In the Garden with Dr. Carver*, five of the sixteen focal students identified the book as one of the two texts in the unit that they learned the most from; six identified it as one of the two most interesting texts in the unit; six identified it as one of the texts their teacher should keep for the following year if she could only keep two; and no focal students indicated that their teacher should skip the book the following year. In fact, nine of the sixteen focal students indicated that their teacher should not skip *any* of the texts when enacting the unit with future classes.

It is telling that many of the focal students selected the trade book, *In the Garden with Dr. Carver*, as one of the two texts that they learned the most from, that they thought was the most interesting, and that their teacher should keep for use with future classes because of how early in the unit students read the book (i.e., it was the second of the six, interactive read-alouds in Unit 4). Similar to findings from Unit 1 interviews, students' Unit 4 interview responses to this set of questions did not reveal a preference for selecting only those texts read more closely in time to the interviews.

Beyond demonstrating a preference for the book, students' interview responses in which they shared reasons for their text selections provided some additional evidence, to complement enactment data, of the ways in which students were taking up ideas related to plants' traits and ecosystem dynamics. For instance, Owen indicated that *Dr. Carver* was one of the most important books to keep in the unit "Because it actually tells you if plants can grow in a certain space." In response to the same question, Makayla indicated that "it teaches you about how much plants need sun." Similarly, Leon explained that the book was important to the unit so "you can learn the difference of one (plant) that can grow but is dying, and (another) one that is…growing bigger than that one." In a final example, Nick recounted that the book was interesting because "at their school, they planted a rose, but it was in the shade and it wasn't really growing well and Mr. Carver was a really good plant expert and helped them grow a lot, but then that one didn't get nothing… It got water, but it didn't get sun, and all of the other ones grew big." These illustrative examples from students' interviews provide additional evidence of the ways in which the *Dr. Carver* text supported students' thinking about environmental factors that affect the growth and traits of plants, focal science ideas from the PBL unit of instruction.

Conclusion

The findings described in Part I of this chapter illustrate the ways in which the text, task, and enactment worked in interplay to create opportunities for and support students' learning of science content and practices, as well as students' development of foundational and disciplinary literacies. While I cannot isolate the features of the text from its enactment, there appeared to be certain affordances associated with the selection of the text, the pairing of the text with the task of planning and conducting a firsthand investigation, and the placement of the text in the curriculum.

The literacy and disciplinary learning opportunities afforded by students' engagement in the task of co-constructing a first-hand investigation, motivated by their participation in the interactive read-aloud, are notable for a number of reasons. The *Dr. Carver* trade book was selected (and the interactive reading guide designed) for this PBL instructional unit because of its potential to achieve multiple aims, including: to (1) serve as a context for eliciting and discussing students' ideas about environmental conditions that support plant growth; (2) engage students in making, sharing, and comparing observations (i.e., afforded by the detailed illustrations and text content of the book); (3) leverage and bolster students' background knowledge about plants' needs and optimal growing conditions, so that *all* students in the class might approach the first-hand investigation with shared knowledge, (4) motivate students to plan and conduct an investigation of variables that affect plant growth, and (5) facilitate students' generation of investigation questions (Ford, 2006; Morrison & Young, 2008; Pappas et al., 2004). These purposes and opportunities are consistent with the NRC Literacy for Science Workshop (2014) vision of using text as a catalyst for supporting students' engagement in science practices.

During enactment, the teacher also supported students' development of foundational skills, such as reading comprehension, by scaffolding their interpretation of ideas in the text and supporting them to closely analyze the words in the text in hand with illustrations. Additionally, prior to reading, the teacher engaged students in making predictions about the content of the text and supported students to make connections to their prior knowledge related to environmental factors that affect plant growth and to George Washington Carver, the scientist featured in the book, in service of knowledge building. Use of reading strategies, such as these, are supportive of students' reading comprehension.

The text and task, as leveraged in enactment, also provided opportunities for the third-graders to learn and use disciplinary literacies. Moje (2015) defined disciplinary literacy as "the specialized skills and codes necessary for reading and writing in various disciplines and technical fields" (p. 257) and has called for elementary-grades teachers to begin the work of apprenticing students to disciplinary reading, writing, and speaking practices as they engage in disciplinary inquiry. In the context of the *Dr. Carver* interactive read aloud and the co-construction of the first-hand investigation, the teacher supported students' active involvement in scientific inquiry by guiding them to co-construct an investigation question, identify investigation variables, determine which variable to investigate and which variables to control in order to design a fair test, and to achieve consensus on a process for carrying out their investigation plan (e.g., placing one set of plants under the desk, another set in the closet, and a final set in the window). It is also clear that students brought to this experience some of the technical scientific language with which they were developing facility through its frequent use in the classroom, such as designing and conducting fair tests, which is integral in conducting scientific investigations.

PART II: Ms. Ollie's Plant Investigation

In this section, I focus on the design and use of a researcher-designed text, called *Ms. Ollie's Plant Investigation*. The text focuses on core ideas related to plant traits and ecosystem dynamics and was designed and placed within the MLs curriculum to extend students' first-hand investigations and evidence-based claims. First, I describe the researcher-designed text, provide an overview of the design features of the text and task, and describe enactment. To address my research questions, I: (a) describe the ways in which the design and enactment of *Ms. Ollie's Plant Investigation* and related tasks supported students' science and literacy learning; and (b) identify modifications to the design of the text and task that might enhance students' science and literacy learning in the context of project-based science instruction.

Design of the Text: Ms. Ollie's Plant Investigation

Ms. Ollie's Plant Investigation is a hybrid genre of text that has both narrative and expository elements. It was designed to: (a) illustrate core ideas related to plant traits and ecosystem dynamics, (b) provide information that connected to and built upon students' first-hand observations and prior knowledge; (c) engage students in scientific practices, such as planning and carrying out an investigation and analyzing and interpreting data in a second-hand way, following their first-hand participation in these practices, (d) provide opportunities for students to interpret and analyze multimodal information (e.g., written text, photographs, data tables), (e) engage students in discussing and responding in writing to the ideas in the text (e.g., through the inclusion of embedded discussion and writing prompts), and (f) extend students' observations and evidence-based claims from their first-hand investigations and text reading by providing conceptual explanations for observed phenomena (e.g., the role of photosynthesis in plant growth) to deepen students' science learning.

The text is written in four parts: (1) Planning the Investigation, (2) Making Observations and Analyzing Data, (3) Making Claims, and (4) Putting the Pieces Together. The text begins by introducing a third-grade teacher, Ms. Ollie, and her class. Like the students in the MLs project, the students in Ms. Ollie's class have been studying "how plants grow and what plants need to survive in their environment." In Part I, Ms. Ollie engages her students in brainstorming how they could plan and conduct an investigation of how light affects the growth of plants. One character in the text suggests that they could put one plant in a sunny spot and the other somewhere dark. Following this portion of the text, MLs students are asked to look closely at a photograph of Ms. Ollie's classroom and recommend, in writing, two locations that fit the student's suggestion (see Figure 7.2).

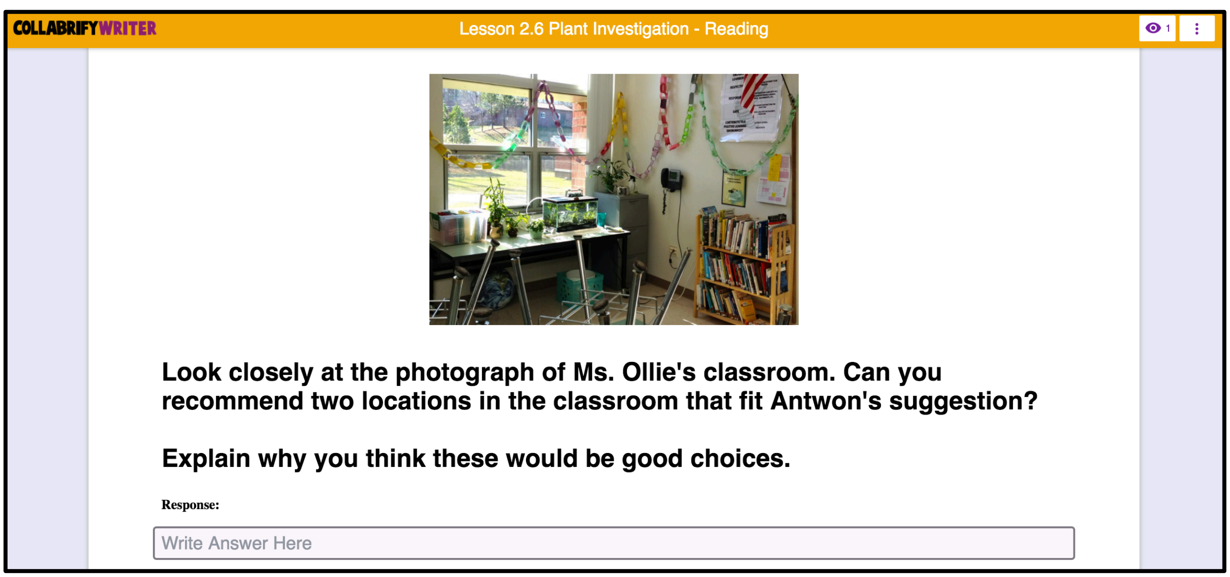


Figure 7.2. Screenshot from Ms. Ollie's Plant Investigation text.

As Part I continues, Ms. Ollie's class begins brainstorming how to design a fair test. Embedded discussion prompts enlist MLs students as more knowledgeable others in "helping" Ms. Ollie's class design a fair test to investigate the amount of light plants need to grow.

Part II of the text focuses on making observations and analyzing data. In addition to providing a description of Ms. Ollie's class discussion and observations, the text contains photographs of the plants from the investigation on Days 7 and 14 of Ms. Ollie's investigation, paired with data tables that represent her students' observation data. Embedded prompts engage MLs students in discussing ideas in the text and entering written responses to ideas in the text.

In Part III, which focuses on making evidence-based claims, students from Ms. Ollie's class introduce competing claims within the text, which MLs students are asked to evaluate. Finally, Part IV of *Ms. Ollie's Plant Investigation* extends MLs students' first-hand and text-based observations by providing conceptual explanations for observed phenomena (e.g., how plants use light, water, and air to grow).

Overview of Enactment

Prior to engaging students in an interactive read aloud of *Ms. Ollie's Plant Investigation*, the teacher supported students to revisit their investigation of how the amount of light affects mung bean traits and growth. The teacher displayed the mung bean plants from each growing condition on a desk in the front of the classroom, invited students to make and share final observations, and engaged the class in collaboratively developing evidence-based claims to answer their investigation question.

After recording claims, the teacher introduced the text, *Ms. Ollie's Plant Investigation*, and engaged students in an interactive read aloud, pausing to allow students to make and share observations of embedded photographs and data tables, to respond to embedded discussion prompts in small groups and as a class, and to enter digital written responses to embedded questions. Recall that in Chapter 5, Part II: The Balloon Rocket Story and Investigation, one limitation revealed through enactment was that, while may students had multiple opportunities to share their ideas as they read and discussed *The Balloon Rocket Story*, this was not true for all students. In response to this limitation, as described here, we began to design opportunities for students to make digital written entries in response to some of the texts included in the curriculum. *Ms. Ollie's Plant Investigation* is one example of this design modification.

Table 7.3

Ms. Ollie's Plant Investigation Enactment Timeline

Lesson	Day	Lesson Activities
How did the different conditions affect the traits of our plants?	Day 1 55 mins.	• Students review data from their investigation of how different amounts of light (no, partial, full) affected the traits and growth of mung beans • Students make evidence-based claims to answer investigation question • Teacher introduces text, *Ms. Ollie's Plant Investigation* • Students participate in an interactive read aloud of the text (Part I)
	Day 2 60 mins.	• Teacher and students continue interactive read aloud of *Ms. Ollie's Plant Investigation* (Parts I-III) • Teacher supports students to revisit claims from their first-hand investigation • Teacher and students conclude interactive read aloud of text (Part IV)

Testing Conjectures

In analyzing and reporting data specific to the design and enactment of *Ms. Ollie's Plan Investigation* and investigation and evidence-based claims tasks, I foreground the following features of the designed MLs learning environment (i.e., *embodiment*): (a) the designed tools and materials, including teacher supports (i.e., lesson plans), digital tools, and multimodal literacy resources (i.e., text); and (2) the task structure. The mediating processes outlined in my conjecture map served as analytic lenses, guiding my analyses of enactment data, artifacts, and interviews. For instance, to understand whether and how mediating processes produced desired outcomes within this lesson, I drew on enactment transcript and individual student artifact data (i.e., written responses to embedded prompts) in order to closely analyze the ways in which these mediating processes emerged and unfolded in the classroom.

The close analysis of transcribed video of lesson enactment allowed me to analyze the ways in which the designed tools and materials (e.g., teacher supports, literacy resources) and task structure produced observable interactions: (a) using tools of reading, writing, viewing, and discussing for meaningful purposes, (b) using scientific ideas and practices, (c) building on prior knowledge and funds of knowledge, and (d) the teacher's instructional moves. Analyzing observable interactions revealed within transcript data in combination with student-generated artifacts and interviews, allowed me to examine whether and how the mediating processes led to the desired outcomes, including: (a) making sense of and synthesizing multimodal texts and (b) using science ideas and practices to make sense of and explain phenomena. I present my findings in the following section.

Findings

In this section, I present findings from my analyses of enactment data (lesson plans, field notes, transcribed video recordings, and student artifacts) and interview data with focal students to respond to my research questions: (1) How did the design of *Ms. Ollie's Plant Investigation* and related tasks support students' science and literacy learning? (2) What modifications to the design of the text and task might better support third-graders' science and literacy learning, in the context of project-based science instruction?

Findings from enactment. I found that the design of the text, *Ms. Ollie's Plant Investigation*, and related tasks synergistically supported third graders' science and literacy learning. I also identified missed opportunities, both within the design of the curriculum resources and the enactment of the lessons, for further supporting the science and literacy learning of all students.

Before reading: Preparing to read by revisiting the firsthand investigation. Analyses of the written curriculum and transcripts of classroom enactment revealed that the teacher leveraged students' science and literacy learning, before reading, by: (1) revisiting their firsthand investigation; (2) making claims and discussing observed variations in plants' traits; and (3) making explicit connections between the firsthand investigation and the text, *Ms. Ollie's Plant Investigation.*

Revisiting the unit driving question and investigation question. One way in which the teacher prepared students to read the text was by revisiting the unit driving question and the firsthand investigation question prior to launching the interactive read aloud. Previous research has identified that teacher moves to illustrate the ways in which unit ideas and activities are related (e.g., connecting to big ideas by revisiting driving questions and investigations) are important for driving student learning in inquiry-based instructional contexts, such as PBL (Puntambekar et al., 2007). In this case, the teacher displayed the mung bean plants that the class was growing in different light conditions (no light, full light, partial light), at the front of the classroom, and engaged students in recalling the unit and investigation questions prior to making evidence-based claims.

Teacher: It's been a while since we've talked about our mung beans, last week…but it's important that we make some claims… I'm going to put full light over here… Partial light will be in the middle. You know what, we'll put full light over here by the windows. And then we'll put (no light on the other side of the classroom) … So, who remembers what our driving question was about the mung beans? …Our big driving question is what, everybody?

Students: How can we grow plants for food in our community?

Teacher: Okay, alright. So, what was the other question that we wanted to know a little bit more about based on your mung beans? …

Cameron: I forgot.

Teacher: Can I start you with "does"?

Cameron: Does the amount of light affect the mung beans' growth?

Teacher: (Scribes the question on chart paper) Okay, so, does the amount of light affect the growth of plants, in this case, mung beans?

This exchange, which launched the lesson, illustrates the way in which the teacher supported students to recall the driving question for the unit (*How can we grow plants for food in our community?*), and revisit their first-hand investigation and the framing investigation question: *Does the amount of light affect the mung beans' growth?* This was important because, as the teacher stated at the beginning of the excerpt, it had been several days since the class had made observations of the plants and recorded data. Because the investigation involved growing plants from seeds, it was necessary for the class to conduct the investigation over a number of weeks in order to observe the mung beans' growth over time, which mean that there were several days between observations. Indeed, Cameron's first response was that he had forgotten the investigation question, but then recalled it with teacher prompting. Thus, the navigational work that the teacher began here, by displaying the plants at the front of the classroom for all the students to see, revisiting the investigation question, and referencing the unit driving question, was important for situating the lesson within the unit of instruction and priming students' thinking. Revisiting the students' investigation question and preparing them to make claims based on evidence was also important for introducing and reading the text, *Ms. Ollie's Plant*

Investigation, because it was designed to mirror and extend the firsthand investigation conducted by students.

Making claims and discussing variations in plants' traits. After revisiting the unit driving question and investigation question, the teacher engaged the class in making claims about whether the amount of light affected their plants' growth and discussing variations in the traits of the plants that were growing in different light conditions. Similar to how the teacher introduced a claim-making activity in other PBL units (discussed in other chapters), she began by supporting students to recall the importance of supporting their claims with evidence and clarifying the difference between a claim and evidence.

Teacher: Based on what we see, what are some claims? And remember, what is essential for claims to have in them? How do we make claims? …What is it that we want to be a part of the claims, Aiden?

Aiden: Evidence.

Teacher: Evidence. We want to make our observations and we want to make some claims based on our evidence… Keyanta, what are your thoughts?

Keyanta: The no light, they're just dropped down like that.

Teacher: Okay, so no light. Can you? No light (Teacher writes on chart paper)

Aiden: It's growing long, but it's going down.

Teacher: Do you agree with that? No Light is long but they're kind of drooping, okay.

Students: (Many talking at once)

Teacher: So, we could say long or tall, but droopy, So, remember, it says, "Does the amount of light affect the growth of plants? So, how would we answer that in a complete sentence and then use our observations as evidence? (several hands raise) Think about what I just said. How can we use our observations as evidence and pull out a complete sentence from that? Let's see, Kaylee?

Kaylee: The no light has, it's trying to droop, like droop and trying to get tangled up with each other.

Teacher: Okay, so no light is long, tall, but droopy…

Kaylee: My evidence is that…

Teacher: Well, okay, hold on. That *is* your evidence, right? You're making an observation. What's our statement going to be? It says, "Does the amount of light affect the growth of plants. Don't worry about evidence right now, but how are we going to answer that question? Nick?

Nick: That…it does because…

Teacher: What does? Wait a minute. It does. What does?

Nick: The amount of light *does* affect it because in full sun its going up, partial it's going sideways, and no light, it's going down.

Teacher: Okay, so let me get at kind of a vote for a minute. Nick said the amount of light does affect the growth of plants…Just give me a thumbs up if you agree with that. Just that statement, not talking about evidence, but the amount of light *does* affect the growth of plants.

At the beginning of this excerpt, the teacher asked students to make a claim to answer the investigation question. It is important to know that, prior to observing the investigation plants displayed at the front of the classroom during this lesson, students made and recorded observations of these plants on three earlier occasions, during which they drew their observations, described the plants' traits (e.g., leaf and stem color) qualitatively, and measured the length of the plants' stems, leaves, and roots using rulers. In the process of asking students to make claims, the teacher also asked what they needed to use to support "a part of" their claims (*What is it that we want to be a part of the claims…?*), to which Aiden responded, "Evidence." As the excerpt continued, these ideas required further clarification. Instead of making a claim to answer the investigation question, Kaylee made and shared an observation of the plants in the no light condition, which prompted the teacher to further distinguish between claim and evidence.

This example illustrates the ways in which the teacher again revisited the relationship between claim and evidence to support the third-graders to engage in the scientific practice of constructing explanations, which includes both claims and evidence. Each time students sought to answer an investigation question about a different phenomenon, the teacher revisited and clarified important components of explaining the phenomenon under investigation. This is an example in which "a revisiting is not a repeating" (Spiro, Collins, & Ramchandran, 2007, p. 96). Because students made evidence-based claims, throughout PBL units, in response to investigation questions that spanned life science, physics, and engineering domains, revisiting the relationships between claim and evidence across domains was important for supporting students to deepen and strengthen their learning with respect to the important elements of the scientific practice of constructing explanations.

As the excerpt continued, Nick made a claim, following which the teacher gauged the level of consensus among the students, who responded almost unanimously that the amount of light *did* affect the growth of the plants. However, as the conversation continued, and the teacher invited students to use their observations of the plants as evidence to support their claim, and further to discuss variations in the plants' traits based on the different light conditions, some disagreement emerged among students regarding whether the plants in full or partial light were healthier, based on their observed physical traits (e.g., color, stem height, leaf size, etc.).

Teacher: Okay, so why does nobody think that these (no light) are the healthiest?

Makayla: …Because they look more like going sideways and they have yellow leaves.

Teacher: Okay, so they're kind of droopy and tangled, they have yellow leaves, but you said something else about the color (earlier in the exchange), about most.

Makayla: Most plants have green leaves and green stems.

Teacher: Okay, so most plants (writing on the chart paper) have green leaves and green stems. Okay, so if I'm looking at Makayla's claim, the amount of light does affect the growth of plants. I know this because the no light plants have yellow leaves and yellow stems. I know this isn't good for the plants because most plants have green leaves and green stems. So, she's giving evidence that she has in her observations and a little bit about what she knows, okay. Somebody else that picked something different? Nick? Which would you pick?

Nick: Partial.

Teacher: You would pick partial, why?

Nick: Because most plants really don't have this color leaves (pointing to the full light condition) and most of them have these color leaves (pointing to partial light condition).

Teacher: So, you think most have the lighter green leaves?

Nick: Yes, like the lime green leaves.

Teacher: (after several more exchanges) Okay, and Makayla said most plants have a green leaf or a green stem. So, you two have a little bit of difference of opinion on the shade of green.

This excerpt illustrates the debate that arose among students about the observed variations in the physical traits of the plants based on the light condition in which they were growing, and what these traits suggested about the health of the plants. As the conversation continued, many other students shared their ideas, and because students were not easily swayed from their positions by their classmates' connections of prior knowledge to in-class observations, the class did not achieve consensus on this issue at this point in instruction. This is important because, based on data from previous enactment years, the text-designers anticipated this disagreement among students regarding whether the plants in the full or partial light condition were growing the best or were the healthiest. In previous enactment years, for example, students claimed that, because the plants in the partial light condition grew taller stems, they were healthier than the plants in the full light condition. Thus, the researchers designed a similar scenario in the text, *Ms. Ollie's Plant Investigation*, to address and extend this conversation.

Connecting the firsthand investigation to the text. After making final observations of their investigation plants, making evidence-based claims, and discussing variations in the plants' traits across light conditions, the teacher introduced the text, and immediately connected the text reading to students' firsthand investigation with the mung beans:

> Ms. Ollie's Plant Investigation is very similar to what we did (in our investigation) …It says, "Ms. Ollie's Plant Investigation. Part I: Planning the Investigation." Give me a

thumbs up if you remember when we planned about how we were going to test the amount of light that our mung beans get.

This brief excerpt illustrates how the teacher introduced the text by telling students that the content of the text was similar to their own first-hand investigation with the mung beans. As she read the first heading, she asked students to indicate whether they recalled their experience planning their own investigation (see Part I of this chapter).

During reading: Supporting students to read and interpret the ideas in the text. Analyses of the written curriculum (e.g., text, lesson plan), transcripts of classroom enactment, and students' digital artifacts (i.e., written responses to embedded prompts within the text), revealed ways in which the teacher leveraged the text and task in support of students' science and literacy learning during reading *Ms. Ollie's Plant Investigation.* During the interactive read-aloud, the teacher facilitated students' reading and interpretation the information in the text in support of their science and literacy learning by: (1) making explicit connections between the text and students' firsthand investigation; (2) engaging students in discussing ideas in the text and responding in writing to embedded prompts; and (3) supporting students to analyze and interpret second-hand data provided in the text.

Making connections between the text and firsthand experiences. Throughout the interactive read aloud, the teacher supported students to make connections between the text and their firsthand experiences. This ranged from the teacher asking students to give a "thumbs up" if something in the text reminded them of something that they did in class or sounded familiar, to more in-depth consideration of similarities between the ideas in the text and students' firsthand experiences (see Table 7.4).

Table 7.4

Connections Students Made Between the Text and First-Hand Experiences

Examples from Enactment Transcripts
Teacher: "Through the clear plastic, the students saw that the cases were each half filled with dark brown soil, with three tiny seeds resting on top." Thumbs up if this sounds familiar. Carter: Us! (Day 1)
Teacher: "Antwon suggested that the class could put one plant in a sunny spot and the other one somewhere in the dark." Aiden: Hey, I thought I suggested that! …Hey, I made that same one! …Didn't I make that same suggestion? (in the context of planning their own firsthand investigation) (Day 1)
Teacher: "After they observed plant growth, measured the size of the stems…" Does this sound familiar? Students: Yes. Teacher: Anything that anybody here did? Students: Yes. Students: Mung beans. Teacher: It sounds like the mung beans that we did, right? (Day 2)
Teacher: I hardly see any leaves there (in the photograph), although I think maybe there's some little yellowish, light yellow ones. "The white stems are still longer, but look how…droopy they are…" Ellie: That's like ours. Kaylee: They're like whoop! (flops over in chair) Teacher: It is very similar to ours, isn't it? Ellie: Yeah, but…ours, like they look like there's still some in there that are like…one's still growing inside of there and its really tall (walks up to the SMART Board and next to students' CD cases on the front table) and most of ours have already grown out and they're all soggy and droopy and stuff like that. Teacher: Okay, but look at, they use that word there too. Ellie: Oh. Teacher: Droopy. (Day 2)

Discussing and writing in response to embedded prompts. Recall that a limitation identified within earlier chapters in this dissertation (e.g., Chapters 4 and 5), was that, during the enactment of interactive read alouds in the first units of instruction, while the teacher sampled many students' ideas in the context of text-based discussions, this was not true for all students. Thus, the curriculum designers began to design texts with embedded prompts, to which students could enter digital written responses. This provided more opportunity for *all* students to enter their thinking and provided additional student artifact evidence regarding whether students were "on the same page" with respect to making sense of the ideas in the text. *Ms. Ollie's Plant Investigation* provided a number of these opportunities. The first of these opportunities occurred near the beginning of the text (in Part I: Planning the Investigation) and engaged students in analyzing a photograph of Ms. Ollie's classroom and suggesting two locations in which the characters could place their plants, which would provide *full light* and *no light* conditions: "Look closely at the photograph of Ms. Ollie's classroom. Can you recommend two locations in the classroom that fit Aaron's suggestion? Explain why you think these would be good choices" (see Figure 7.2).

> Okay, so there's the picture of the classroom… You have space to write in yours. Which two spaces…and Aaron suggested a sunny spot and the other one somewhere dark. So, where might that be. Make some suggestions. You've got a place to write. You write…your response in complete sentences: "I think they should…" alright? Writing in complete sentences. "I think they should…" and then tell what you think they should do. "I think…" should be your first two words. I think they should place one plants, blank, and be specific. There's a picture of the classroom, so where do you think that they should place (the seeds)?

As students entered their written responses, identifying two locations to place the plants and explaining their choices, the teacher circulated and repeated and clarified directions as she conferred with individual students. Student responses to this prompt illustrated the ways in which this enabled the teacher to sample more students' ideas and also to gather evidence regarding the ways in which students were analyzing and interpreting ideas in the text. Figure 7.3 provides examples of students' entered responses.

I think they should put on under the desk behind the crate because the spot is dark, another spot to put it on top of the tank by the window because it is right by the window and sun is flowing in.

oder the table becase its dark there the suny one be on the window

I think they should put the plant in the sun on the desk and for dark they can place it under the desk,because if it is in the dark under the desk you could see both of the plants and check on them at one time because it is right by each other and yo wont have to go all over the place and go check on the plants.

I think they should place one plant for the Sunny one one the window because it as a lot of sun and the no sun under the book shelf because it is dark very dark.

Figure 7.3. Example focal student entries (top to bottom): Ellie, Leon, Raelyn, and Zayn.

Example focal student entries, illustrated in Figure 7.3, show the range of students' responses. All focal students who entered responses, were able to identify two locations aligned to the suggestions of the character, Aaron, in the text. However, not all students (e.g., Leon) provided the reasoning behind their selections, in writing. After students entered their responses to this question, the teacher paused the interactive read aloud for the day and continued reading on the next day of instruction, inviting students to share portions of their written entries with the class and then continued reading to reveal the locations that the characters in the text chose.

Other embedded prompts were designed to spark discussion among students, but were not designed for students to enter written responses. One such set of prompts asked students to reflect on an investigation plan proposed by one of the characters in the text and to evaluate whether the proposal was an example of a fair test. If students determined that the proposal did not meet the requirements for fair tests, the prompt asked students to consider how they could help Ms. Ollie's class plan fair tests if they wanted to investigate how the amount of light and the amount of water affects plant growth (see Figure 7.4).

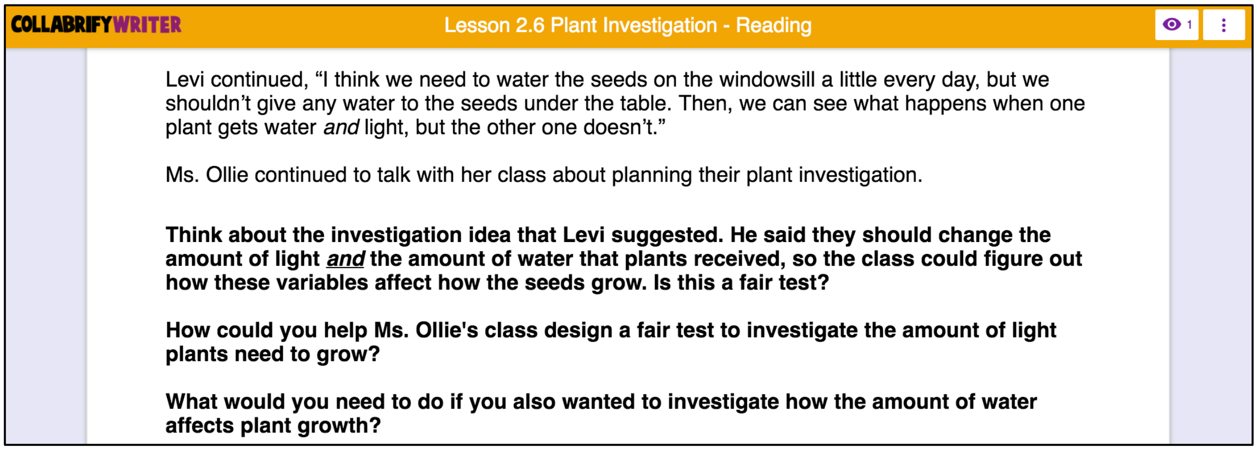


Figure 7.4. Example discussion prompts from *Ms. Ollie's Plant Investigation.*

During enactment, after reviewing the discussion prompts, the teacher instructed students to turn and talk with a partner or small group about each of the embedded discussion questions as she circulated and conferred with individual, pairs, and small groups of students. After providing time for students to discuss these ideas with one another, the teacher brought the class back together to share and compare their ideas and recommendations for Ms. Ollie's class.

Teacher: Alright, so, very first question… Is that a fair test?

Students: (many at once) No!

Teacher: It's not. So, somebody tell me why it's not a fair test. Why is it not a fair test? I agree with you, but why Malik?

Malik: Because they're only doing sunlight.

Teacher: …Okay, Kaylee, what are your thoughts? …Kaylee?

Kaylee: I think it's not a fair test because if you don't put water and they do put water, and it's under the table, you don't know which one killed the plant.

Teacher: Tell me what you mean, you don't know which one killed the plant. I know what you mean, but can you explain it just a little bit more.

Kaylee: Like, you water the plant or you don't, you should put it more in the sunlight in both, you both put one in the sun. Put them both in the sun and just give one water.

Teacher: Okay, so that's, so you kind of jumped down and you explained how could we help them find…how the amount of water affects a plant. So, what needs to happen in order for it to be fair? You said it. Owen?

Owen: They both need to get the same amount of water or else it won't be a fair test.

Teacher: It won't be a fair test because why…?

Owen: Because they wouldn't know which one affects the plant.

This excerpt illustrates the ways in which the teacher engaged students in discussing embedded prompts in the text, both in small group and whole class participation structures, which were designed to support students to analyze text ideas and to connect to their prior knowledge and experiences in the present and previous MLs units. Embedded prompts, in this case, were designed to play a similar role to the suggestions included in interactive reading guides that were developed to support the teacher's enactment of MLs texts. Recall that, in response to finding that few text-based discussion questions posed during interactive read alouds in earlier units elicited high-level thinking, such as analysis or elaboration, researchers began to design more interactive reading guides to support the enactment of rich text-based discussions (see Chapter 4). As this excerpt continued, after talking in small groups, students shared their ideas about the final two discussion questions, which recruited the class in helping Ms. Ollie's students to design fair tests for different variables they might investigate (e.g., light, water).

In a final example in which students were prompted to turn-and-talk with a partner, and then respond in writing to an embedded question in the text, students were asked to identify which of two claims presented by characters in the text they agreed with and to describe the evidence that supported their thinking (see Figure 7.5).

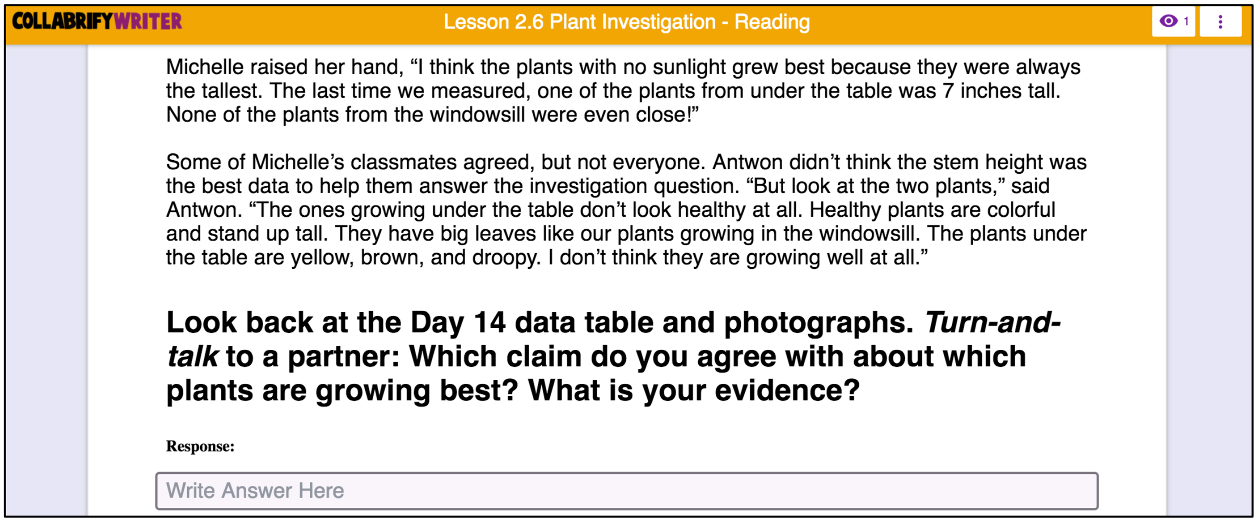


Figure 7.5. Excerpt from *Ms. Ollie's Plant Investigation* and embedded writing prompt.

After reading this portion of the text (see Figure 7.5), the teacher reviewed the prompt and made a connection to the ideas that students debated during the previous day of instruction:

> …You're going back to day 14 observations…There's two different claims about the plants that are growing the best. What is the evidence? Which one do you agree with? What are the two claims…? We kind of had these similar claims, I think, earlier this week… What I'm asking you to do is turn and talk to someone, and then you have to decide which claim do you agree with…and then, write it in your response box… This might be, "I agree with the claim that…" That might be a great way to start it. "I agree with the claim that says…"

As students entered their written responses, identifying the claim with which they agreed and describing the evidence from the Day 14 data in the text (e.g., data table and photographs) that supported the claim, the teacher circulated and repeated and clarified directions as she conferred with individuals and small groups of students. Student responses to this prompt illustrated the ways in which this enabled the teacher to sample more students' ideas and also to gather evidence regarding the ways in which students were analyzing and interpreting ideas in the text. Figure 7.6 provides examples of students' entered responses.

> So my evidence the droopy and tall ones are not healthy at all so i think the ones by the ones by the light is healthy.It is bent it tells you on the day 14 on the no light one.It is 7 inches but falling over.Full light is not even bending or falling down all of the full light is standing.bright

> the window was the healthiest. because it stands up straight.

> I think that Antowon is right because the plants in sunlight look more green and if i saw the no sunlight and the sunlight i would get the sunlight because it looks more green and healthy plants have green leaves and stems but the no light has yellow leaves and a yellow stem.

> I think the full sun light because it is healthier.

Figure 7.6. Example focal student entries (top to bottom): Carter, Aiden, Makayla, and Julia.

These examples of focal students' written entries illustrate the range of written responses students gave to the embedded prompt. All focal students agreed with the claim that the plants growing in the full light condition displayed healthier traits than those growing in the no light condition. Students responses revealed variations in their use of data from the Day 14 table and photographs, as evidence to support the claim with which they agreed. The written responses, in this case, served to provide the teacher evidence of all students' sense-making at this point in the text.

Analyzing and interpreting second-hand data (e.g., using photographs and data tables). A final way in which the teacher engaged students in reading and interpreting the information in the text was by supporting them to analyze and interpret second-hand data provided in the text, in the form of photographs and data tables. Recall that the characters in the text planned and conducted a similar investigation to the one that the third-graders conducted firsthand. Having already participated in a similar experience positioned the third-graders as "more knowledgeable others" (Litowitz, 1993) as they read. In one example near the beginning of the text, the teacher invited students to make observations of a set of photographs, which illustrated the characters' investigation setup.

Teacher: "Ms. Ollie asked her class to gather around the table to look at the plants and to describe what they noticed." So, if you look at the two different CD cases (used as planters), what do you notice about what they (the characters in the text) are seeing? Any observations? Ellie, what's your observation?

Ellie: They haven't germinated yet.

Teacher: Okay, they haven't germinated yet. "'They look the same,' Maci said…" Any other observations, Nick?

Nick: That in seed one, the first one, you can see that one in the middle but in the second one you can't.

Teacher: Okay, so in the second one, maybe we're only seeing one seed? … "Ms. Ollie asked them to look closely at the soil and tell her about it. 'The soil is moist, and it's dark brown,' Mia observed." How do you think they know that it's moist? Dark brown is certainly something that we can say, "Okay that's dark brown," but how do we notice that something is moist?

Aiden: If it's a darker shade than it usually is.

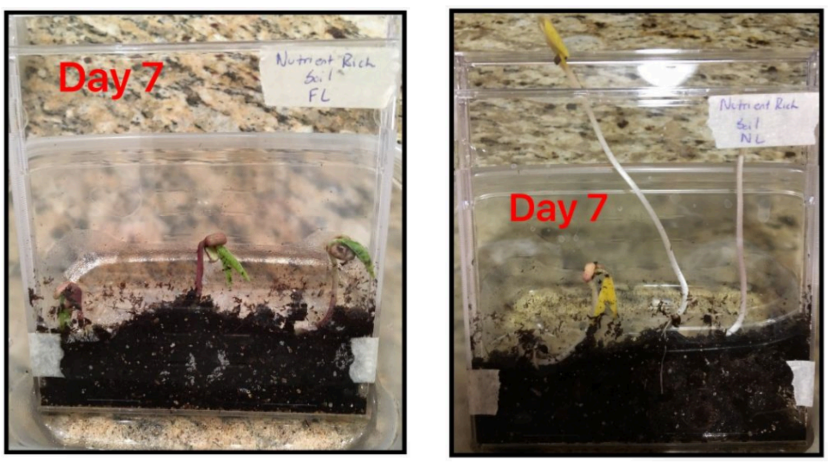
Teacher: Okay, certainly, water will kind of add a darker tone to it. Anything else that might give them a clue that they're moist? Makayla?

Makayla: Maybe there's like those water drops on there.

Teacher: There's kind of water droplets on there, right? …You can see the water, right? You can almost kind of see some of the water on there.

This excerpt provides on example of how the teacher engaged the class in analyzing and interpreting data along with the characters in the text. She iteratively moved back and forth between the character's dialogue and eliciting her students' own observations using the photographs provided.

In another example that illustrates the ways in which the teacher supported students to analyze and interpret second-hand data in the text, she engaged students in sharing what they noticed about the Day 7 photographs and data table (see Figure 7.7, below), and in translating across modes of representation.



Day 7 Observations			
Amount of Light	**Stem Height**	**Color**	**Leaf Size**
Full Sunlight (windowsill)	***Plant 1:*** ½ inch	Red stems	***Plant 1:*** ½ inch
	Plant 2: 1 inch	Bright green leaves	***Plant 2:*** ½ inch
	Plant 3: 1 inch		***Plant 3:*** ½ inch
No Sunlight (under table)	***Plant 1:*** 1 ½ inches	White stems	***Plant 1:*** ½ inch
	Plant 2: 3 ½ inches	Yellow leaves	***Plant 2:*** ½ inch
	Plant 3: 2 inches		***Plant 3:*** ½ inch

Figure 7.7. Day 7 photographs and data table from the text.

Teacher: "After seven days, Ms. Ollie brought the plants back to the table and invited the class to describe them again. This is what they saw." So, this is nutrient rich soil with full light, and this is nutrient rich soil with no light.

Students: (Gasping as they looked at the photographs) …

Kaylee: I noticed, I've got an observation! …I've got an observation about that.

Teacher: So, what do you guys notice about their plants? …Curtis, what do you notice?

Curtis: I noticed something really unusual. No light is taller than full light.

Teacher: Okay, no light is taller than full light. What else do you notice? Julia?

Julia: The no light, the stems are like trying to find their way up…

Teacher: Okay, so you're kind of thinking that the no light is trying to find the light. We kind of talked about that last week (in the context of the first-hand investigation), didn't we? … [several more turns of talk, with students sharing observations] Zayn?

Zayn: I noticed how like…the full light is shorter but it looks healthier because it's leaves hang out and its stem is like purplish and then the seed is brownish and then the no light, it's white and then the leaves are yellowish color, and then although they're bigger, doesn't mean that they're healthier.

At the beginning of this excerpt, the teacher read aloud the text that introduced the photographs and the data table and then engaged students in sharing their observations, first focusing on the two photographs. Curtis began by sharing an observation that he found unusual: "No light is taller than full light." Then, Julia's comment, as noted by the teacher, extended Curtis' observation and connected to an earlier class discussion in which the class proposed that the plants growing in the no light condition might be growing taller because they were "looking for the light." Finally, after several other students shared their observations of the photographs, this portion of the exchange concluded with Zayn's comparisons of the plants' traits across the full and no light conditions.

After closely analyzing and sharing observations using the photographs in the text, the teacher then asked students what they noticed about the second-hand data provided in the data table for Day 7. Students shared what they noticed specific to the types of data the characters in the text recorded, as well as patterns that they noticed in the data. In addition, the teacher supported students to translate across modes of representation.

Teacher: What do you notice about their data, Kaylee?

Kaylee: (Walks up to SMART Board) It says like their data for…day 7 observation, amount of light. I noticed that they actually like put half an inch and stuff like, and they described what their colors were.

Teacher: So, they measured in inches. They described the colors, alright…Nick, is there something that you really want to say about their data?

Nick: That, in stem height for no sunlight, it's bigger.

Teacher: Right, and it kind of goes right along with the pictures, right? You guys said that the no light versus the full light, the no light definitely is taller and that's certainly what their table of information represents, okay?

Nick: And in color, the red stem and the bright green leaves are different from the no light with the white stems and yellow stems.

Teacher: Okay, so they're talking about what they observed with their eyes and they're putting it right in their table.

At the beginning of this exchange, Kaylee shared the types of data that were represented in the table, such as measurements and descriptions of the plants' colors. Nick followed by sharing his observation that the stem heights for the plants growing in the no sunlight condition were larger than those growing in the full light condition. At this point, the teacher made a connection back to what students observed in the photographs: "It kind of goes right along with the pictures, right? You guys said that…the no light definitely is taller and that's certainly what their table…represents." Supporting students to translate across modes of representation in this way is important because, as noted in previous chapters, scientific literacy and communication are inherently multimodal and in order to read, interpret, and produce science text in service of knowledge building and engaging in scientific practices, students must develop skills for interpreting and translating across multiple modes of representation (Lemke, 2004). Additionally, because every mode of representation has both affordances and limitations, any single representation only partially reflects a phenomenon (Freebody, Luke, & Gilbert, 1991). Therefore, supporting students to translate across multiple representations may support them to deepen their understandings of phenomena under study and to consider ways in which different modes can communicate similar information in different ways, such as the information represented in photographs and data tables.

Constraints of the text and task revealed through enactment. In addition to the ways in which the text, task, and the teacher's enactment supported students' science and literacy learning, my analyses also revealed limitations of the design and enactment of the written curriculum. One possible limitation was that, while the text was designed to connect to and extend students' discussions about variations in plants' traits based on environmental variables (e.g., sunlight), and to provide information about what plants need to grow and be healthy, there was considerable disagreement among students about whether the plants growing in full or partial light conditions, in their own investigation, were healthier. Additionally, the class was split about physical traits that were indicative of plants' "health," prior to, during, and following the interactive read aloud. For instance, a number of students shared the idea, prior to reading, that the plants growing in the partial light condition displayed the healthiest traits, for a number of reasons: (1) plants growing in partial light had longer stems than those growing in full light; (2) some students preferred the "lime green" color of the stems and leaves of the plants growing in partial light to the "dark green" and "purplish" leaves of those growing in full light; (3) and, finally, some students expressed concerns that the plants growing in full light conditions might receive too much sun and, thus, suffer from "heat stroke."

Although the final part of *Ms. Ollie's Investigation* (Part IV: Putting the Pieces Together), connected back to students' firsthand investigations as well as to the traits of plants students observed around their school and community to serve as contexts for providing information about why plants need light, water, and air to grow, and how these environmental features support plants' growth, there was limited evidence that this information altered the thinking of the students who claimed that the plants growing in partial light displayed the healthiest traits. Some research has illustrated the promise of refutation text for supporting students' conceptual understanding and reading comprehension in science education (Sinatra & Broughton, 2011). Refutation texts are designed to engage readers in making direct comparisons between their prior knowledge and the ideas in a text, in order to directly address and refute commonly held prior conceptions in support of knowledge building consistent with scientific explanations provided in the text. In our revisions of *Ms. Ollie's Plant Investigation*, we are considering ways in which we might incorporate features of refutation text in Part IV, to better support all students' knowledge building in this context.

Findings from student interviews. In this section, I describe findings from interviews conducted with focal students, which provided additional insights about students' perceptions of – and learning with – Unit 4 texts. The portion of the interview protocol, addressed here, consisted of a subset of questions from the larger protocol, which addressed all texts from the unit of instruction. In this section, I focus on the same subset of interview questions described in Part I of this chapter.

Specific to the researcher-designed text, *Ms. Ollie's Plant Investigation*, four of the sixteen focal students identified the book as one of the two texts in the unit that they learned the most from; five identified it as one of the two most interesting texts in the unit; six identified it as one of the texts their teacher should keep for the following year if she could only keep two; and one focal student indicated that their teacher should skip the book the following year. This focal student, Lucas, explained his rationale as follows: "We already like did this (investigation), so what would be the important thing if we already learned about this? …We already did our mung beans." While Lucas did not feel that the *Ms. Ollie* text was imperative to the unit, other focal students expressed that they thought the text was important and interesting precisely because the students' in Ms. Ollie's class conducted a similar investigation to the one that MLs students conducted firsthand (see examples in Table 3).

Table 7.5

Focal Students' Responses: What Was So Interesting About This Text?

Excerpts from Interview Transcripts
Aiden: "Because they actually grew mung beans like we did."
Carter: "That they almost did the same thing as us."
Makayla: "That they did the same thing that we did and…the seeds that were in the sun look better than the ones that were…under the table."
Malik: "It looked just like the one that the class did and I was looking for my plants to see if it was the exact one that we did 'cause we used mung beans and…I forgot which one they used but it was kind of similar to ours."

Conclusion

The findings described in Part II of this chapter illustrate the ways in which the text, task, and enactment worked in interplay to create opportunities to support students' learning of science content and practices, as well as students' development and use of foundational and disciplinary literacies. As noted in previous chapters, while I cannot isolate the features of the text from its enactment, there appeared to be certain affordances associated with the design of the text, and the placement of the text within the curriculum. By revisiting the firsthand investigation and supporting students to make and share final observations and evidence-based claims, the teacher leveraged the written curriculum by supporting students to both build and activate prior knowledge before reading *Ms. Ollie's Plant Investigation.* This work positioned students as "more knowledgeable others" (Litowitz, 1993) as they read and interpreted information about a similar investigation conducted in Ms. Ollie's class by fictional students.

Recall that *Ms. Ollie's Plant Investigation* was designed to both mirror and extend students' observations and claims made in the context of their firsthand investigation, creating a reason for students to revisit, reflect upon, and deepen their understandings of the elements of the scientific practice of planning and conducting an investigation and of core ideas related to plant traits and ecosystem dynamics (e.g., features of the environment that affect plants' traits). Thus, in the context of "helping" Ms. Ollie's class plan and conduct an investigation, the third-graders had an opportunity to revisit important scientific practices as "experts," and also to continue to deepen their knowledge of how environmental variables affect plants' physical traits. While the idea of planning and conducting fair tests, for instance, was introduced during the second MLs unit of instruction, students were still building knowledge with respect to this practice, as the design of a fair test can look quite different in different science domains and investigative contexts. As mentioned above, this is consistent with Spiro's argument that "a revisiting is not a repeating" (Spiro et al., 2006). Thus, this "revisiting" in the context of reading and discussing the *Ms. Ollie* text was important for supporting students to deepen and strengthen their understanding and use of the practice of designing investigations using fair tests.

With respect to students' literacy learning, the design of the text and task, in hand with the teacher's enactment created opportunities for students to analyze, interpret, discuss, and navigate across multiple modes of representation, including written text, photographs, and data tables, as well as the third-graders' own physical plants displayed in the classroom. As Lemke (2004) noted, scientific literacy and communication are inherently multimodal and in order to read, interpret, and produce science text in service of knowledge building and engaging in scientific practice. Reading and interpreting the *Ms. Ollie* text created opportunities for students to develop and use skills related to interpreting and translating across multiple modes of representation. Indeed, enactment data provided evidence that the teacher supported students to interpret multiple, as well as to move across forms of representation, through highlighting connections between students' interpretations of photographs and data tables within the text.

Further, the addition of response boxes, in which students could enter digital written responses to embedded prompts within the text, provided evidence of the ways in which all students were making sense of the ideas in the text and bringing their prior knowledge to the text interpretation. Whereas in previous units the teacher's ability to sample all students' ideas in response to embedded discussion prompts or suggestions in interactive reading guides was limited, the embedded writing prompts provided information about all students' sense-making.

CHAPTER VIII. CONCLUSIONS AND IMPLICATIONS

In this final chapter, there are six major points for discussion. In the first section, I revisit the conjecture map that I introduced in Chapter 3 of this dissertation and discuss the ways in which the development and revisiting of this map supported the design and conduct of my study, and informed revisions to the literacy-related resources within the MLs curriculum. This section is followed by one in which I synthesize findings relevant to the design and enactment of the eight focal texts/text sets – two from each of the four third-grade MLs units of instruction. In the third section, I examine possible constraints of the MLs curriculum and instruction in the focal classroom. Next, I focus specifically on limitations and implications of the present study. Finally, I close with a discussion of directions for future research.

Conjecture Map

Because the MLs curriculum is a comprehensive instructional intervention, with many features hypothesized to support knowledge building and literacy development, I used conjecture mapping to identify theoretically salient features of the design, specific to literacy integration in the MLs unit, and to map how these features are predicted to work together to produce specific outcomes (Sandoval, 2014). For this dissertation, I foregrounded and analyzed conjectures related to the design (or selection) and enactment of MLs texts and tasks in order to address my research questions: (1) How do texts and related tasks, designed for – and enacted in – project-based science instruction, support or constrain third-graders' (diverse with respect to academic achievement) knowledge building and development of foundational and disciplinary literacies?

(2) How might modifications to texts and tasks, within the designed curriculum, better support third-graders' knowledge building and literacy development?

Recall that my *high-level conjecture* was that – for students who demonstrate diverse levels of achievement – deep science and literacy learning with text require the use of literacy tools of reading, writing, viewing, and oral language for meaningful purposes in the context of PBL. One salient feature of the designed MLs curriculum that I analyzed in this study was the *tools and materials* in the form of literacy resources (e.g., texts of multiple modes, media, and genres), digital tools, student notebooks, and teacher supports (e.g., lesson plans, interactive reading and viewing guides). Another salient feature of the designed MLs curriculum was the *task structure* (i.e., types of tasks) in which the learners were expected to engage. As Sandoval (2014) explained, "Designs do not lead directly to outcomes… In learning environments, the use of particular tools for specific tasks enacted in specific ways is intended to produce certain kinds of activity and interaction that are hypothesized to produce intended outcomes" (p. 23). Thus, for evidence of the *mediating processes* that enabled the tools, materials, and tasks to support desired outcomes, I observed specific interactions between the teacher and the students and among students, and also analyzed class- and student-generated artifacts, as well as interviews, specific to text reading and related literacy tasks.

Finally, as illustrated in my conjecture map in Chapter 3, examples of *desired outcomes* included students (a) using and interpreting science discourse/talk, (b) making sense of and synthesizing multiple multimodal science texts, (c) using science ideas and practices to make sense of and explain phenomena, and (d) developing increasingly sophisticated written and visual science texts. Focusing my data collection and analysis on observable interactions among participants and materials, as well as artifacts that participants produced from their activity, guided my construction of a case and allowed me to uncover the ways in which the participants engaged with designed intervention and ultimately to uncover evidence of *desired outcomes*. Thus, in my analyses and findings for this dissertation, I foregrounded the literacy *tools and materials* in interaction with other features of the MLs *embodiment* (e.g., task structure) and *mediating processes* in order to construct a case and respond to my research questions.

I revisited my conjecture map as the curriculum unfolded in the classroom and during the process of data analysis, evaluating and seeking to refine original conjectures based on collected data. Testing conjectures calls for data collection and analysis methods that can identify whether the mediating processes emerge through the enactment of an intervention, providing evidence that connects mediating processes to elements of the designed intervention (Sandoval, 2014). I used my analyses to identify evidence of the ways in which the literacy *tools and materials*, the *task structure*, and features of the teacher's enactment supported and/or constrained students' knowledge building and literacy development. While this process pointed to modifications to the conjecture map (Figure 8.1), the process of analyzing conjectures was also useful as a tool for identifying changes to particular features of the designed *tools and materials* and *task structures* in order to better enable mediating processes and therefore, better approximate desired outcomes.

Conjecture map revisions. While I identified "use and interpret science discourse/talk" as a *desired outcome* in my original conjecture map, for this dissertation study, I did not analyze this component in isolation. Rather, to address my research questions, I found it more productive to analyze classroom discourse/talk within the context of the other three *desired outcomes* identified, as a necessary component of each: (a) make sense of and synthesize multiple, multimodal science texts; (b) use science ideas and practices to make sense of and explain phenomena; and (c) develop increasingly sophisticated written, visual, *[and spoken]* science texts. Thus, in my revised conjecture map, I removed this component, and embedded "spoken text," within the final desired outcome (see Figure 8.1): "Develop increasingly sophisticated written, visual, *and spoken* scientific texts."

Further, because of my emphasis on the design and enactment of texts and tasks within the larger designed curriculum, I chose to foreground certain features of the embodiment within my analyses and findings across units of instruction. Foregrounded features of the embodiment included *tools and materials* and *task structure*. Thus, while I identified *discursive practices* ("Social and disciplinary norms for sense-making discussions") as an important feature of the *embodiment*, I did not closely analyze this feature as I tested conjectures specific to my research questions. Conjectures specific to this component should be tested in future studies. Doing so may support, challenge, or reveal additional modifications to the conjecture map presented here.

Similarly, while I also identified *participant structures* as an important feature of the *embodiment*, I did not closely analyze or address this feature in isolation as I analyzed data and tested conjectures specific to my research questions. Further, within the umbrella of a "collaborative inquiry" participant structure, are many participant structures (e.g., whole class, small group, partner), each of which might be closely analyzed for its role in achieving *desired outcomes*. However, my data analysis and case construction process revealed the *participant structure* of collaborative inquiry as an important and consistent component of *task structure* within the MLs curriculum. Thus, in my revised conjecture map, *task* and *participant structures* are combined (e.g., "Tasks that engage students in collaborative inquiry, using science practices, and knowledge building).

Perhaps the most important change within my revised conjecture map is to the arrows that articulate my design and theoretical conjectures. These revisions are based on my analyses of the ways in which designed MLs texts and tasks, enacted in particular ways, produced *mediating processes* that led to *desired outcomes* in the focal classroom. Recall that my initial map from Chapter 3 identified many individual components of the *embodiment* (e.g., teacher resources, student notebooks, digital tools) as leading to individual components of the *mediating processes* (e.g., using scientific ideas and practices, student notebook entries). However, my findings did not support this teasing apart of the relationships among the *embodiment, mediating processes*, and *desired outcomes*. Instead, and as discussed across my findings chapters, my findings suggested that it was the various features of the designed intervention in interplay with one another – particular tools and materials used in combination to complete particular tasks – that produced the interrelated activity, interactions, and artifacts identified as *mediating processes*. Further, my findings revealed that, in many instances, the various observable interactions and participant artifacts were simultaneously in play, in support of producing *desired outcomes.* Therefore, I collapsed the arrows that articulate my design and theoretical conjectures to illustrate the importance of the interplay among features of the *embodiment* and *mediating processes* for producing *desired outcomes*. These revised conjectures require further testing and refinement across future iterations of the MLs curriculum.

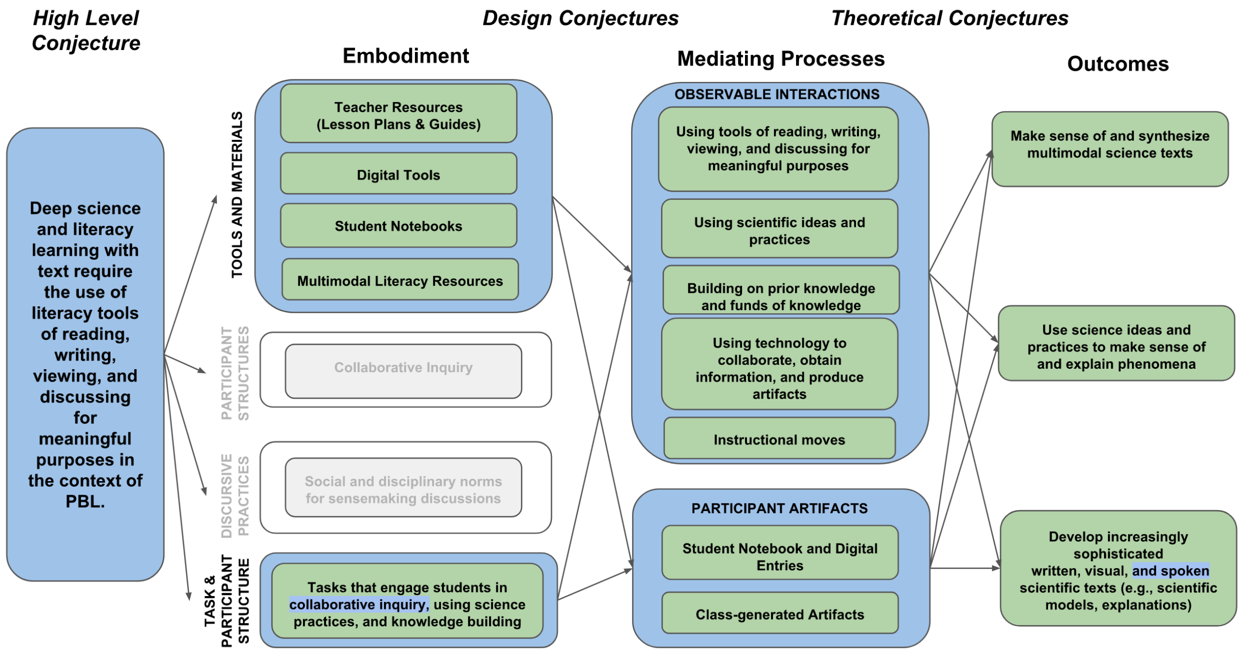


Figure 8.1. Revised conjecture map for supporting science and literacy learning with text in elementary project-based science.

Synthesis of Findings: Emerging Themes

As illustrated across findings chapters, a major finding of this dissertation study was that the texts, tasks, and enactment worked in interplay to create opportunities for and to support students' learning of science content and practices, as well as students' development of foundational and disciplinary literacies. Although I cannot isolate the features of the texts and tasks from their enactment in the classroom, there did appear to be affordances associated with the design of the texts, the pairing of texts and tasks, and the placement of the texts in the MLs curriculum. In the sections that follow, I discuss three key themes that emerged across my findings chapters. These themes include: (a) pairing texts with meaningful tasks in the context of PBL created opportunities for, and supported, students' science and literacy learning; (b) the design and enactment of texts and tasks provided dual opportunities for knowledge building and literacy learning in PBL, as the teacher and students used text *in service of* engaging in disciplinary knowledge building and practice; and (c) texts served as tools for creating and sustaining coherence in PBL.

Pairing of texts and tasks. One theme of this dissertation is that pairing texts with meaningful tasks in the context of project-based instruction created opportunities for, and supported, students' science and literacy learning. As discussed in Chapter 2, there is general consensus among literacy researchers of the value of engaging students in meaningful literacy activity. Indeed, current research evidence suggests that when students read and write texts for meaningful purposes during instruction, they experience gains in reading engagement and comprehension (e.g., Guthrie et al., 2004, 2009; Purcell-Gates et al., 2007; Romance & Vitale, 1992, 2001). The findings of the present study build upon this body of research by illustrating ways in which PBL texts and tasks can be designed to support this aim.

The focal texts featured within this dissertation were designed to be paired with tasks that called for students' meaningful use of disciplinary core ideas and engagement in scientific practices, such as developing scientific models, designing solutions, planning and conducting investigations, and analyzing and interpreting data. For example, in Unit 1, *For Squirrels It's Headfirst and Down* was designed to motivate and provide information to support students' engagement in scientific modeling; in Unit 2, *The Balloon Rocket Story*, was designed to illustrate scientific practices, such as planning and conducting fair tests and closely observing phenomena, as well as to provide a context for and motivate students' to plan and conduct their own investigation; in Unit 3, the *Snowy Owl Data Table* was designed to engage students in analyzing and interpreting data. My analyses of enactment data suggested that the design features were taken-up and leveraged in the context of project-based science instruction.

Across focal texts, I found that the pairing of disciplinary texts with disciplinary tasks provided meaningful purposes for the third graders to read, view, analyze, and interpret multiple multimodal science texts. While this finding was consistent across the four units analyzed, it played out in various ways based on the design of texts and tasks, and the teacher's enactment in the classroom. For example, recall that in Unit 1, I found that the teacher used the text, *For Squirrels It's Headfirst and Down*, and a modeling task to scaffold students' science and literacy learning by supporting her students to identify and use information in the text in order to revise their scientific models. Further, the teacher leveraged the pairing of the text and task to scaffold students' understanding of and engagement in the scientific practice of modeling. The pairing of this text and task was important because: (a) the text provided important information about disciplinary core ideas necessary for productive engagement in the modeling tasks, and (b) engaging in the modeling task provided a meaningful purpose for students to read, interpret, and apply the information in the text. I imagine that this is the kind of productive pairing of texts and tasks that Pearson (NRC, 2014) was calling for when he argued that science texts should be used as a "catalyst for engaging in science practices" (p. 13).

Recall that a common design feature of the focal texts, across units of instruction, was that the texts were designed or selected to provide information that connected to and built upon students' first-hand experiences, observations, and knowledge within and beyond the unit of instruction. Reading instruction that engages students in drawing on their prior knowledge and experiences as they read supports comprehension (e.g., Brown et al., 1996; Saunders & Goldenberg, 1999). A common finding across units was that the design of the texts, tasks, and the teacher's enactment supported students to activate and build upon their prior knowledge from first-hand experiences and texts read earlier in the unit. For example, prior to reading the Lonnie

Johnson text set and applying text ideas to revising the designs of students' own toys in Unit 2, the teacher engaged students in first-hand observation, investigation, and discussion of a Super Soaker toy prior to reading. During this time, students also had opportunities to share prior knowledge and experiences from beyond the classroom. The teacher then leveraged these and other shared experiences from the unit (e.g., designing their own toys, interviewing kindergartners for design feedback) to support students' sense-making with the Lonnie Johnson text set, and then to apply their learning from text to their own engineering designs.

Dual opportunities for knowledge building and literacy learning. Another important finding from this dissertation is that the design, pairing, and enactment of texts and tasks created dual opportunities for knowledge building and literacy learning in the focal third-grade classroom. We know from the studies of Cervetti et al. (2012), Connor et al. (2017), Fang and Wei (2010), Guthrie and colleagues (2004, 2009), Palincsar and Magnusson (2001), and Romance and Vitale (1992, 2001), that science texts can be used in the elementary grades to promote knowledge building and literacy learning. The findings of the present study build upon this body of research by illustrating ways in which PBL texts and tasks can be designed and enacted in order to support this aim.

As described in Chapter 2, science texts are particularly well-suited to providing opportunities to *use* reading, writing, speaking, and listening, as tools to build and communicate knowledge about the world (Hapgood & Palincsar, 2006/2007; NRC, 2014). Science texts are conceptually rich and often include multiple modes of information (e.g., prose, images, graphs, diagrams, charts, etc.) or representations of phenomena. Indeed, Lemke (2004) argued that, in order to read, interpret, and produce science text in service of knowledge building and to engage in scientific practices, students must develop skills of interpreting multiple modes of representation. Across units of instruction, I found that the texts, tasks, and the teacher's enactment worked in interplay to create opportunities for and to support both students' knowledge building and the development of foundational and disciplinary literacies. A focus on knowledge building around disciplinary core ideas was a common design feature across texts and tasks. Further, analyses indicated that the teacher leveraged the designed and selected texts and tasks in service of students' knowledge building around core science ideas.

Concurrent with a focus on knowledge building, MLs texts and tasks also provided opportunities for and supported students' learning of foundational and disciplinary literacies. For instance, I found that the design of texts and tasks, in hand with the teacher's enactment, fostered students' use and development of foundational literacy skills, particularly vocabulary development and reading comprehension. For example, in Unit 4, during the interactive read aloud of the trade book, *In the Garden with Dr. Carver*, the teacher supported students' comprehension of multimodal information by scaffolding their interpretation of ideas in the text and by supporting students to synthesize multimodal information (i.e., words and illustrations), using reading strategies such as making predictions and visualizing information in service of knowledge building. In Unit 1, students selected and read texts to build knowledge about a particular organism, while simultaneously using and developing vocabulary and comprehension, which was facilitated by guiding questions that supported students to locate and communicate key ideas, and later to synthesize ideas across multiple texts. Finally, in Unit 2, while reading *The Balloon Rocket Story* and engaging in the balloon rocket investigation, the teacher supported students to deepen their vocabulary knowledge (e.g., force, friction), and then to use the vocabulary introduced in the text within the context of planning and conducting a firsthand investigation and writing evidence-based claims.

In addition to recruiting and supporting students' development of foundational literacy skills, I found that the texts and tasks provided multiple opportunities to support students' learning and use of disciplinary literacies as they engaged in knowledge building. Moje (2015) defined disciplinary literacy as "the specialized skills and codes necessary for reading and writing in various disciplines and technical fields" (p. 257) and called for elementary-grades teachers to begin the work of apprenticing students to disciplinary reading, writing, and speaking practices as they engage in disciplinary inquiry. However, while some research at the secondary level has begun to explore the potential of disciplinary literacy instruction and the design of learning environments that scaffold the learning and use of disciplinary literacies, less is understood about the ways in which young students might be supported to learn and use disciplinary literacies. Across MLs units, texts were paired with specialized science and engineering tasks that called for students to both interpret and communicate information about science phenomena. These tasks included developing scientific models, writing scientific explanations, planning and conducting investigations, analyzing and interpreting data from their own and other investigations (e.g., *Snowy Owl Data Table*), and examining investigations and findings in a second-hand way (e.g., *The Balloon Rocket Story, Ms. Ollie's Plant Investigation*).

One scientific practice that requires specialized literacy skills and codes is scientific modeling. In science, models are developed and used to represent a system under investigation, to ask questions and develop explanations, to make predictions, and to communicate ideas (NRC, 2012a). In Unit 1, the teacher leveraged unit texts to support students to interpret and communicate information through developing scientific models. In this context, students used information from text to support the development of scientific models that explained how squirrels survive in their habitat and how organisms interact in a particular environment. Further, the class co-constructed methods for clearly communicating information in their models, such as clearly representing and labeling model components and relationships.

In another example of the ways in which students learned and used disciplinary literacies, after students read the trade book, *In the Garden with Dr. Carver*, the teacher supported students to collaboratively plan an investigation by engaging in specialized literacy skills of co-constructing an investigation question, identifying investigation variables (seeded in the trade book), determining which variables to control in order to design a fair test, and developing a process for carrying out their investigation plans. Further, in this context and others, such as the *Snowy Owl Data Table* and *Ms. Ollie's Plant Investigation*, students read and interpreted information in data tables to develop evidence-based claims.

Texts as tools for creating and sustaining coherence in PBL: Design and enactment. A final theme from this dissertation is that the texts served as tools for creating and sustaining coherence in PBL in support of students' literacy and science learning. Guthrie et al. (1999) explained that teachers create coherence by linking materials, activities, and contexts in ways that enable students to make rich connections. Further, Puntambekar et al. (2007) found that when teachers illustrated relationships among unit ideas and activities (e.g., connecting to big ideas by revisiting driving questions and investigations), these instructional moves drove student learning in inquiry-based contexts, such as PBL. My findings suggest that coherence can also be strategically embedded within the designed materials and tasks in an instructional intervention, which may support teachers to make these links explicit in the context of instruction. I found this to be the case with respect to the texts and related tasks designed and enacted within the third-grade MLs units of instruction. The findings of the present study illustrate ways in which PBL texts and tasks can be designed and enacted in order to support this aim.

Across units of instruction, findings indicated that the design of the texts and tasks, and the teachers' enactment supported students to activate and build upon their prior knowledge by connecting to the unit driving question, to earlier first-hand experiences, and to other texts read and interpreted within PBL units of instruction. Recall that prior to reading or viewing focal texts across units, the teacher supported students to make rich connections among texts and activities by setting purposes for reading and preparing students to read by making explicit connections to students' prior knowledge and experiences. While the teacher sometimes did this spontaneously, these connections were often explicitly identified within the texts themselves (i.e., prompting students to reflect upon prior unit experiences), or within the interactive reading guides designed to support the teacher's enactment (i.e., prompting the teacher to make connections to prior unit experiences).

In one example, in Unit 1, as the teacher introduced *For Squirrels It's Headfirst and Down*, she supported students to make connections to what they had been learning throughout the week: "I want you to think and recall some of the things that we've done this week…we have been talking about adaptations…We've been talking about structures that squirrels have. We have been learning about the things that they do." In this way, the teacher primed students' thinking by linking to related activities in the unit. Later, as students completed their modeling tasks, the teacher linked back to the text, using the text to both create and sustain coherence in the unit of instruction.

In another example, in Unit 3, as the teacher introduced the video, *Secrets of the Snowy Owl*, she again supported students to make connections to the unit driving question, as well as students' prior learning and experiences in the unit: "Yesterday we came up with a question… In addition to how can we help birds in our community thrive and grow up, what was the question that we talked about yesterday." The students then shared and discussed what they recalled about their first-hand activities from the previous day and the teacher supported them to make connections to specific portions of students' initial discussions of and brainstorming about bird migration, in preparation for viewing the video. These links, designed into instructional materials, were leveraged and made explicit by the teacher, creating coherence and enhancing meaningfulness across the unit of instruction.

Finally, perhaps the best example of the ways in which texts served as tools for creating and sustaining coherence in PBL in support of students' literacy and science learning comes from Unit 2. By tracing connections made to both the Lonnie Johnson text set and the *Balloon Rocket Story* following their enactment in the classroom, I found that these texts and related tasks served as touchstones that supported both instruction and student learning throughout the rest of the unit. The teacher and her students drew on the shared experiences of reading, viewing, and interpreting the texts and related tasks. After their enactment, these texts and tasks served as background knowledge that the class drew upon and leveraged as the unit of instruction progressed, in service of new learning. I argue that making these explicit links back to information in the texts and accompanying tasks served as tools for creating and sustaining coherence in students' learning experiences across the unit of instruction.

Critiques of the Curriculum and Instruction and Related Design Implications

While my analyses revealed a number of ways in which the design and enactment of texts and tasks, in the context of PBL, created opportunities for and supported students' science and literacy learning, the curriculum and instruction also warrant some critical attention. Identified constraints of the curriculum and enactment included: (a) instances in which the curriculum provided insufficient educative supports for teachers; (b) instances in which the curriculum materials and enactment might have missed opportunities for supporting students' science and literacy learning; (c) uneven participation among students; and (d) limited opportunities for students to construct meaning with text without the advantage of firsthand experience. As I describe each of these constraints, I also indicate implications for revisions to the designed curriculum (e.g., *materials and tools, tasks, etc.*) that might better support *mediating processes*, and thus, better approximate *desired outcomes*.

Design and use of interactive reading guides. Interactive reading guides may play an important role in supporting teachers' and students' interactions with text. However, my analyses revealed instances in which MLs curriculum supports for engaging students in text-based or video-viewing discussions might have enhanced instruction, but were not included, as well as instances in which interactive guides were included, but might be revised to better effect. As a result of these findings, the MLs design team has begun to design more interactive reading guides (*tools and materials*) and to revise current reading guides to better support teachers to engage students in productive talk about text (*mediating processes*) in support of comprehension, synthesis, and translation across multimodal science texts (*desired outcomes*). Evidence of the teacher's use of interactive reading guides in the focal classroom was described in the findings chapters for Unit 2 (*From Water Squirter to Super Soaker; The Balloon Rocket Story*), Unit 3 (*Secrets of the Snowy Owl* video), and Unit 4 (*In the Garden with Dr. Carver*). Recall that the interactive reading guides included information to support: (a) teachers' content knowledge; (b) students' interpretation of "big ideas" in the text; (c) students' analysis of multiple modes of information; (d) students' interpretation science vocabulary; (e) students' engagement in making connections between information in the text and their first-hand experiences and investigations within and beyond the unit of instruction. Across these lessons, I identified ways in which the teacher took up the reading guide suggestions and leveraged these tools in support of students' engagement in reading, text-based discussion, synthesis of information across multiple tasks, and tasks. These findings are promising and illustrate that, when provided, the teacher drew on many of the suggestions within interactive reading guides to support students' interactive reading and discussion of texts during MLs instruction.

While my analyses pointed to the potential of the interactive guides, they also revealed limitations in the written curriculum and enactment that inform the future design of and revisions to interactive reading guides. Thus, one critique of the MLs curriculum was that there were instances in which supports for engaging students in text-based discussions during interactive read-alouds or video viewing were not included in curriculum materials (e.g., *For Squirrels It's Headfirst and Down*), or may be revised to better support enactment (e.g., *Secrets of the Snowy Owl, Snowy Owl Data Table*). Recall that, during the interactive read-aloud of *For Squirrels It's Headfirst and Down*, although the teacher frequently paused during reading to check for student understanding, and to support students to interpret the images in the text, I found that many of the teacher's questions did not elicit high-level thinking, such as synthesis or elaboration. These types of questions are important for supporting students' comprehension during discussion (Soter et al., 2008). Further, the teacher did not prompt students to make explicit connections between the ideas in the text and their related observations and investigations. These findings reflect missed opportunities to engage students in synthesizing multiple text sources and modes.

Missed opportunities related to supporting students to interpret and synthesize multiple texts and to make connections between texts and experience were further revealed in Unit 3: *Secrets of the Snowy Owl* and the *Snowy Owl Data Table*. For example, I found that both during and after viewing the video multiple times, there was no focused return to the idea of migration and the ways in which the information in the video might build upon students' prior learning about migration. This was also the case as the class worked to interpret the Snowy Owl data table. In addition, in these lessons, the teacher missed opportunities to make connections between the *Secrets of the Snowy Owl* video and data table. Teachers need support to engage students in productive talk about text and to synthesize multimodal sources of information in support of sense-making. These limitations echo the earlier findings of Arias et al. (2015) and Prain and Waldrip (2006) and indicate that the teacher and students may have benefitted from additional educative support, in the form of interactive reading guides. These missed opportunities have implications for the future design of and revision to interactive reading guides, as well as for teacher professional development, both of which might more explicitly provide suggestions for making these connections to the "big ideas" of the PBL unit and supporting students to identify intertextual connections across multiple, multimodal texts.

A final critique related to the design and use of the interactive reading guides is that when interactive reading guides were provided, the teacher sometimes missed opportunities to incorporate embedded prompts and suggestions. For instance, in Unit 4, during the interactive read aloud of *In the Garden with Dr. Carver*, while the teacher leveraged some of the suggestions within the reading guide, she did not incorporate the majority of the suggestions provided. This was particularly the case for those suggestions related to supporting students to analyze and interpret the literary elements of the book. There are many possible reasons that the teacher may have chosen not to incorporate some of the suggestions into her enactment of the interactive read aloud of the text. One possible reason is constraints on instructional time project-based science. Another possibility is that the teacher intentionally chose to leverage only suggestions in the reading guide that were specific to supporting students' knowledge building, scientific observations, and discussion of science ideas to support their later planning of a firsthand investigation. Regardless, because of the MLs curriculum's dual aim of supporting student learning goals outlined in NGSS as well as the CCSS for English language arts in the context of project-based science instruction, this finding has implications for the redesign of interactive reading guides and teacher professional development.

Thus, my findings indicated that this type of educative curriculum feature has potential for supporting elementary-grades' teachers to engage students in productive text-based discussions, to teach comprehension of science text in an inquiry mode, and to use text to teach and support students' engagement in scientific practices. The inclusion of educative features, such as these, will be important for the future design of PBL curriculum, as well as other curriculum materials that seek to integrate literacy and practice-oriented science instruction.

Design of text. There were also instances in which the curriculum missed opportunities to support students' conceptual understanding specific to disciplinary core ideas. One example comes from Unit 4, in which students conducted their own investigation of how features of the environment affected plants' traits and read *Ms. Ollie's Plant Investigation*. While the text was designed to connect to and extend students' discussions about variations in plants' traits based on environmental variables, and to provide information about what plants need to grow and be healthy, there was considerable disagreement among students about whether the plants growing in full or partial light conditions, in their own investigations, were healthier, as the class was split about physical traits that were indicative of plants' health. This has implications for the revision of text and other curricular materials. For instance, in revisions of *Ms. Ollie's Plant Investigation*, the MLs design team is considering ways in which we might incorporate features of refutation text into this reading in service of support knowledge building (Sinatra &

Broughton, 2011). The text could, for example, read: "You may think that the longer the stem, the healthier the plant, but, this is not accurate. In fact, the need for light may be causing the plant to grow a very long stem."

Uneven participation among students. Another possible critique of the curriculum and instruction was that there was uneven participation among students, particularly in the context of whole-class discussions. For example, particularly in Unit 2, when students read the Lonnie Johnson text set and the *Balloon Rocket Story*, while many students in the class had multiple opportunities to participate directly in demonstrations and collaborative investigations, and to share their ideas as they read and discussed the ideas in the text, this was not true for all students. While the teacher leveraged many opportunities to sample a number of students' ideas as they read and discussed text, and participated in firsthand experiences, this sampling does not guarantee that all students were "on the same page" with respect to reading and interpreting the ideas in the text and productively building on their prior knowledge and experiences. Indeed, across units, select students' voices are much more prominent than others. Because of this limitation, the MLs design team began to design opportunities for students to make digital written entries in response to many of the texts included in the curriculum. Recall that the technology tools in the MLs curriculum not only had the capability of embedding response boxes within digital texts, but also afforded the opportunity for students to collaboratively enter responses with peers and share these ideas with the teacher and classmates in real time. Evidence of the ways in which these designed technology *tools and materials* were revised and enacted in the classroom (*mediating processes*) in support of students' reading and interpretation of multiple, multimodal texts (*desired outcomes*) was presented and discussed in findings specific to the enactment of *Ms. Ollie's Plant Investigation* in Unit 4.

Opportunities to construct meaning with text. Another possible critique of the designed curriculum was that it provided few opportunities for students to construct meaning with text without the advantage of firsthand experience. For instance, across MLs units and texts, students' reading was heavily scaffolded by firsthand experiences. Recall that prior to reading *For Squirrels It's Headfirst and Down* in Unit 1, students had already made a number of observations of squirrels around their school and closely analyzed photographs and videos that highlighted squirrels' body structures. Additionally, in Unit 2, students explored, analyzed, and investigated with Super Soakers prior to reading about the design of the toy and how the parts work together as a system. Also, in Unit 2, students simultaneously read about and investigated balloon rockets in a firsthand way. Further in Unit 4, prior to reading and discussing *Ms. Ollie's Plant Investigation,* students planned and conducted a similar firsthand investigation in the classroom. This is an important critique because the MLs team is committed to providing students the opportunity and support to construct mental models of text by interpreting and synthesizing the ideas in the text without always having the benefit of firsthand experiences. Indeed, some science phenomena cannot feasibly be explored in a firsthand way in K-12 classrooms. While we do not aim to limit students' access to rich firsthand experiences, we seek to strike a balance, in which students might be productively supported to use and interpret text in order to access ideas and phenomena that are not easily experienced in classroom settings.

Additional Implications of this Research

In addition to implications specific to iterative design of the MLs project-based learning curriculum, this research also has implications for other designers of PBL curriculum, the design of pre- and in-service education and professional development for teachers, implications for the availability and use of text-resources in elementary-grades classrooms, and implications for educational policy. I address each of these implications in the sections that follow.

Curriculum design. This research has implications for the design of texts and related tasks in PBL curricula. My findings illustrated that the texts in the MLs curriculum played important roles specific to: (a) providing students with dual opportunities for knowledge building and literacy learning; (b) motivating and supporting students' engagement in meaningful tasks; (c) creating and sustaining coherence in PBL instruction. In addition to these roles, which I unpacked in the themes identified above, my findings also illustrated the potential of providing supplemental texts related to the big ideas of a PBL unit of instruction.

First, I found that the design and enactment of the focal texts provided students with dual opportunities for knowledge building and literacy learning. They also served to motivate and support students' engagement in disciplinary tasks. All focal texts were designed or selected to connect to and build upon students' prior learning in the units of instruction, and also to illustrate disciplinary core ideas identified within the NGSS. This was combined with an emphasis on supporting students' development and use of foundational literacies (e.g., supporting students to construct meaning with multiple, multimodal texts and to interpret vocabulary important for making sense of science phenomena) and disciplinary literacies (e.g., reading disciplinary texts for disciplinary purposes). I found that these opportunities were largely taken up by the teacher and her class during PBL instruction.

Additionally, I found that texts and tasks were designed and enacted *in service* of supporting students' knowledge building and engagement in science practices; this was an important driver of student learning in the PBL units. None of the texts across the MLs units of instruction were designed to be enacted as resources solely for delivering information. Rather, the texts, the tasks with which they were paired, and their placement in the curriculum were designed to drive student activity and learning in particular ways, which placed science and literacy in interplay. However, this begs questions about the role of texts as tools for "providing information" in the context of project-based science instruction. The MLs project continues to work toward finding a productive balance between providing opportunities for students to construct meaning with text and opportunities for students to "figure out" phenomena through firsthand exploration and investigation. One way in which the curriculum designers have attempted to strike this balance is by placing firsthand explorations of phenomena and sense-making with text in interplay. For example, within some texts, students tack back and forth between reading and interpreting the ideas in text and participating in firsthand investigation (e.g., The Balloon Rocket Story). In other instances, texts are designed to explicitly reference and build upon students' firsthand experiences (e.g., Ms. Ollie's Plant Investigation). However, as noted previously, there are some phenomena that students may not be able to explore firsthand in the classroom. In these cases, there are questions about *how much* information text should provide. These are important considerations questions for PBL curriculum designers.

My findings also illustrated the ways in which texts and related tasks can serve as anchors or touchstones within a PBL unit of instruction that can support the teacher's instruction and students' learning. Sometimes this coherence arose as a result of designing opportunities to revisit particular texts across a unit of instruction; at other times, the teacher or students spontaneously made these connections. Because of the ways in which some of the texts served to create and sustain coherence throughout units of instruction, designers of project-based curricula should attempt to identify and provide curricular support for such opportunities within PBL instructional units.

One challenge inherent within this design work is the complexity of making decisions about the distribution of time and attention both within and across lessons in the curriculum. In design revisions, the MLs design team continues to grapple with how to balance learning opportunities that engage students in firsthand exploration and investigation of phenomena with opportunities for students to read and build meaning with text, in service of knowledge building and engaging in scientific practice. While challenging, finding this balance, and strategic ways to integrate students' firsthand and text-based learning experiences to synergistically support students' sense-making continues to be a MLs aim.

Finally, although represented in only one unit of instruction (Unit 3: How can we help the birds in our community grow up and thrive?), the teacher reported the provision and students' access to supplemental texts related to the big ideas of the unit as an important driver of student interest and engagement in reading. Additionally, most of the focal students reported reading one or more of these supplemental books during the PBL unit, and some of those who did not read them explained that it was because there were none left, due to high demand. Because of the overwhelmingly positive response to the opportunity to obtain and read supplemental texts connected to the big ideas and unit driving question, this is a design feature that designers of PBL curriculum should consider as they develop project-based units for young students.

Availability and use of informational text. This case study also has implications for the availability and use of text resources in elementary-grades classrooms. The design and enactment of the MLs PBL curriculum, as described in this study, illustrated one embodiment of PBL's potential to provide opportunities for students to read, interpret, and produce a wide range of text types as they explore real-world problems, including written, oral, digital, and multimodal texts (Wade & Moje, 2001). In other words, strategically designed PBL curriculum that integrates disciplinary and literacy learning, has the potential to address issues related to the scarcity of informational and digital texts, as well as related instruction in elementary-grades classrooms (Brenner et al., 2009; Duke, 2000; Jeong et al., 2010). PBL curriculum that designs integral and meaningful roles for multiple, multimodal texts may be one response to overlapping calls in education for deeper learning, a focus on knowledge-building in literacy instruction, learning and using multiple literacies, and increased availability and use of informational text in elementary-grades classrooms.

Policy. Finally, this dissertation study has implications for educational policy, specific to the distribution of instructional time and foci in elementary-grade classrooms. The studies of Cervetti et al. (2012), Connor et al. (2017) Fang and Wei (2010), Guthrie and colleagues (2004, 2009), Palincsar and Magnusson (2001), and Romance and Vitale (1991, 2001), indicated that science texts can be used in the elementary grades to enhance reading outcomes, such as vocabulary, fluency, and comprehension, as well as to build science knowledge. This dissertation study builds on this body of work, illustrating ways in which science text might be designed and enacted in the context of elementary-grades project-based science instruction, in ways that emphasize disciplinary knowledge building and practice. However, engaging students in this kind of learning calls for the reallocation of instructional time in elementary-grades classrooms, where currently, little instructional time is dedicated to disciplinary (i.e., science, social studies) learning. The teacher in the focal classroom was generous in her allocation of time to project-based science instruction (approximately 45 minutes a day, Monday through Friday); yet, time constraints still challenged the full enactment of curriculum texts and tasks, and required skipping certain portions of lessons, or abbreviating class discussions and tasks. Reallocation of time in elementary classrooms will require shifts in the value placed on disciplinary instruction for young students. Policy-makers have an important role to play in making deeper – and disciplinary – learning feasible in the early grades.

Limitations of the Study

One limitation of this study is that I had to make choices within each of the PBL units of instruction about the texts and instructional events that I would closely analyze and present within my findings chapters. In order to provide a rich description of the texts themselves, as well as the ways in which the enactment of texts and related tasks unfolded in the classroom, it was important to limit the number of texts and tasks that I analyzed. To this end, while each of the four third-grade MLs units featured many texts, I limited my analysis to two texts (broadly defined as including traditional print texts, images, video, graphical, etc.) per unit of instruction.

Recall that I used the following criteria to guide my selection of text and related instructional events for close analysis: I aimed to select texts and tasks that (a) were diverse in genre (e.g., biographical, hybrid narrative and informational, informational, historical nonfiction, etc.), (b) featured multiple modes of representation (e.g., traditional print text, images, video, graphical, etc.), (c) featured diverse participation structures (e.g., whole class, small group/partner, individual), and (d) engaged students in a variety of tasks (e.g., creating scientific models, analyzing and interpreting data, developing scientific explanations, planning and enacting first- or second-hand investigations, making sense of core ideas and practices, etc.). My analyses of student interview data also served as a source of guidance in my selection of texts and instructional events for analysis. While I developed and followed a plan for making these choices strategically, it is possible that the texts and tasks that I selected for analysis and presentation in my findings chapters are not fully reflective the variety of texts and related tasks included in the third-grade MLs units of instruction, or the ways in which these events unfolded within the focal classroom across the schoolyear.

Directions for Future Research

In the final section of this dissertation, I identify several areas for future inquiry suggested by the present study. First, my use of design-based research and case study methods in this dissertation allowed me to look closely at the design of texts and tasks for project-based learning, and the ways in which the focal teacher and her students enacted and took up designed learning opportunities. Using multiple data sources enabled me to analyze and describe the interplay among the design of the texts and tasks, the placement of texts and tasks within the curriculum, and their enactment in the focal classroom. These analyses allowed me to uncover how the design of texts and tasks, as enacted in the focal classroom, supported the science and literacy learning of third-grade students, who were diverse with respect to academic achievement.

My analyses of the texts themselves and the curriculum resources designed to support their enactment, enabled me to identify common design features across texts and tasks. Further, observation data in the form of field notes, audio recordings, and video recordings of PBL instruction enabled me to closely analyze the teachers' instruction, and the interaction and talk between the teacher and students, and among students, around designed texts and tasks. Analysis of student- and class-generated artifacts allowed me to analyze the ways in which students took up and represented ideas from text in their work. Finally, the interview data that I collected with students and their teacher provided multiple perspectives on students' sense-making with – and reactions to – the texts and tasks designed and selected for the PBL units. Thus, the close study the focal classroom enabled me to uncover "dimensions and dynamics of classroom living and learning" specific to the design and enactment of texts and related tasks as they unfolded across a year of PLB instruction (Dyson, 1995, p. 51).

While I collected and analyzed multiple sources of data for this study, much remains to be explored. First, the field would benefit from additional design-based and rich implementation studies exploring the integration of text and literacy in project-based approaches. This study focused on the design and enactment of curriculum materials within a single PBL intervention, at one grade level, and in one focal classroom. Thus, replication in different contexts at the same – and across – grade levels would complement the present study by providing further evidence to support, extend, or complicate the findings reported in this dissertation. While PBL has gained momentum in K-12 classrooms in recent years, there are still few rich implementation studies, particularly in the elementary grades. Further, specific to literacy education, there are too few models of what literacy integration can look like within these approaches, illustrating whether and how PBL might enlist and support students' use of literacy tools of reading, writing, and oral language.

In addition to complements to the present study, the field would benefit from a *synthesis* of qualitative studies specific to literacy integration in PBL. The benefits of working across multiple cases, conducted in different school contexts and across grade levels, are many. For example, a synthesis of design-based studies that look closely at the design and enactment of literacy curriculum materials and instruction could result in a set of design principles for the integration of literacy in PBL. A synthesis of studies has the potential to reveal common design principles across interventions (e.g., designed for different grade levels and/or subject-areas), and instances in which design principals may differ in important ways. In this study, many design features were common across texts and tasks; however, other curriculum designers and researchers may identify a different set of design features essential to their work. Further, a synthesis of qualitative studies could reveal common affordances and limitations of text integration in PBL, which could inform future curriculum design.

We also need to know more about the integration of literacy in PBL, through the use of alternative methodologies, such as experimental studies. Halvorson et al. (2012) identified benefits to literacy and social studies learning for students who participated in an integrated literacy and social studies PBL intervention. However, additional experimental studies are needed to investigate the impact of PBL approaches on elementary-grade students' reading, writing, and oral language. As reflected in the present study, it is now the norm for a wide range of academic achievement levels to be represented in a single elementary-school classroom. Thus, another important avenue for exploration, through experimental methods, is whether integrated literacy instruction in PBL differentially supports the literacy learning of students who are performing at different levels, as measured by standardized assessments of academic achievement. While it is possible that elementary project-based approaches could effectively support the literacy learning of students performing at a range of achievement levels, we need experimental studies to address this.

Experimental studies exploring the efficacy of integrated literacy instruction in PBL for diversely achieving students should be complemented by implementation studies that employ qualitative and multiple methods. These studies should closely examine students' differential literacy learning pathways and opportunities in project-based approaches. In the present study, I selected focal students who were diverse with respect to literacy achievement and reflected the demographics of the classroom with respect to race and ethnicity; however, my findings focused primarily on interaction and activity at the classroom level. Future studies should look much more closely at elementary-grade students' differential literacy learning opportunities and experiences in PBL, particularly for underserved populations of students, such as those from low-income backgrounds, students receiving special education services, and English language learners. These studies have the potential to reveal opportunities and obstacles for supporting the knowledge building and literacy development of underserved populations of students in project-based instruction, and adaptations that might optimally support student learning in particular contexts.

A final area for future inquiry suggested by the present study is professional development to support teachers' integration of text and literacy into project-based instruction. Additional studies should investigate the ways in which teachers take up professional development opportunities as they learn to enact project-based instruction, and how they incorporate, or fail to incorporate, professional learning into their teaching. This is particularly germane to efforts to bring PBL to scale and includes the study of both the design and outcomes of face-to-face or online professional development, as well as educative curriculum materials. Specific to educative curriculum designed to support the integration of literacy, we need to know more about teachers' use of educative features included in lesson plans and other materials, such as interactive reading guides or the texts themselves. For example, this kind of research, in the context of project-based science instruction, would allow researchers to identify how educative curriculum features might be designed in order to support teachers to teach comprehension of science text in an inquiry mode, provide differentiated literacy instruction for diversely achieving students, teach challenging scientific practices, and engage in instruction that places scientific and language literacy in interplay.

APPENDICES

Appendix A: For Squirrels, It's Headfirst and Down! (Unit 1 Student Text)

For Squirrels, It's Head First and Down!

Red Squirrel climbing down an oak tree

Have you ever seen a squirrel climbing down a tree like the one in the photograph?
How does a squirrel's body help it do that?
Squirrels have special features or structures that allow them to climb down trees head first.
What do you think those structures are?

There are four.


Squirrel hanging onto the side of a tree

If you think that a squirrel's claws help it to climb, you are right. With its sharp claws, a squirrel can grip the bark of a tree. The strong grip of the front claws allows the squirrel to hold on while it moves its back feet. Then the back feet can hold on while the front feet move.

The claws are attached to strong legs and arms. Those legs and arms are another structure that allow the squirrel to climb down head first.

If you think that the tail of a squirrel is important, you are right again. The squirrel's tail helps it to keep its balance. A squirrel can move its tail to keep it steady while it's on the ground and while it's climbing up or down.


Squirrel running along a tree branch

To find out about the last feature that helps squirrels to climb down a tree head first, look closely at the back feet of the squirrel in these photographs.

Did you notice that the back feet of the squirrel in the first photograph are pointed back, while the back feet in the second photograph are pointed toward the front?

The squirrel has an amazing anklebone that allows it to rotate its back feet. If you could do what the squirrel can do, you could twist your foot so your toes are where your heels are!

The squirrel's anklebone can swivel, or turn from side to side. It can rotate, or turn. When the anklebone turns, it can lock in place. This lets the squirrel move freely in many different directions. Because of its special anklebone, the squirrel is able to change its position quickly if it needs to.

To sum up, the squirrel has four structures, or body features, that allow it to climb down a tree head first.

Image Attributions

Appendix B: Example Structure-Function Card – Eastern Garter Snake

(Unit 1 Student Text)

How do Eastern garter snakes survive in their environment?

Where do Eastern garter snakes live?
Garter snakes can live in many places because they can adapt to different environments. Some of their habitats, or places they live, are woodlands, meadows, hillsides, and marshes. Garter snakes like to live in wet, grassy areas. You can often find garter snakes near water, like streams, ponds, and lakes. As long as there are places for them to hide, garter snakes will live in neighborhoods or cities too. In these places, they like to hide under plants, rocks, or logs.

What do garter snakes eat?
Garter snakes mostly eat worms, toads, frogs, fish, snails, other snakes, and leeches. Sometimes, garter snakes will eat small mammals or baby birds.

What eats garter snakes?
Garter snakes are eaten by many predators. Some of their common predators include bullfrogs, fish, snapping turtles, and other snakes. Some birds eat garter snakes too, like hawks, blue herons, and crows. Other predators are squirrels, foxes, and raccoons.

How do you think garter snakes survive in their environment?

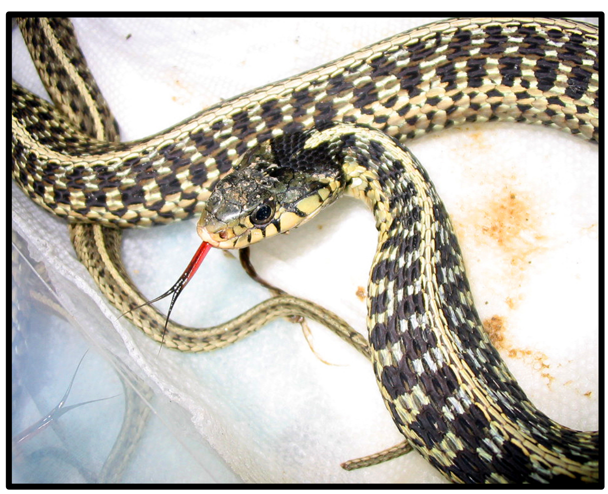
How do Eastern garter snakes survive in their environments?	
Skin Garter snakes have three stripes down their body. These stripes make it hard to see them as they move through grassy places. Garter snakes' light stripes and dark bodies camouflage them, or help them blend in with the land around them. This helps them hide and escape from predators.	
Jaw Garter snakes can detach their jaw. Their detachable jaw lets them open their mouths very wide so they can swallow their prey whole.	
Tongue Like other snakes, garter snakes have a forked tongue that serves a very special purpose. Snakes stick out their tongue to sense the things in their environment. Even though snakes have nostrils that they use to smell, their tongues are what give snakes a great sense of smell. Garter snakes flick out their tongues to help them pick up the scent of nearby prey or predators. They also use their tongue to track other garter snakes.	

Image Attributions

Common garter snake By Wilson44691 (Own work) [Public domain], via Wikimedia Commons

Medusa By Matt Reinbold/Flickr

Garter Snake Eating Fish By Bandelier National Monument/Flickr

Appendix C: From Water Squirter to Super Soaker: How Lonnie George Johnson Changed Water Games (Unit 2 Student Text)

From Water Squirter to Super Soaker: How Lonnie George Johnson Changed Water Games

Not so long ago, on hot days in the summer, children laughed while they chased each other squirting water from small plastic water squirters. Nobody got very wet, but it was a nice way to cool off. All that changed in 1991 when the Super Soaker went on sale. With the Super Soaker, you could drench someone with a single blast of water.

Where did the Super Soaker come from?
The story begins in Alabama in the home of Lonnie George Johnson.

Lonnie George Johnson was born on October 6, 1949 in Mobile, Alabama. His mother worked as a nurse's aide and his father worked as a driver at local Air Force bases. Lonnie's father also worked on his car and fixed some things around the house. He and Lonnie worked on projects and built things together.

Lonnie was always curious about how things worked. According to Mrs. Johnson, “Lonnie tore up his sister’s baby doll to see what made the eyes close.” When he was 13, Lonnie built a go-kart using scrap from junkyards and a lawn mower engine. At this time, Lonnie decided to become an engineer because he realized that “engineers were the people who did the kind of things that I wanted to do.”

In high school, Lonnie continued to design and build things. Over a year, he used inexpensive items or parts he found to make a robot he called Linex. Scraps of metal became the robot’s body; electronics from an old jukebox and his brothers’ walkie-talkies allowed him to control the motion of Linex. Can you tell how he used the reels he got from his sister’s tape recorder?

Juke Box

Lonnie Johnson and Linex

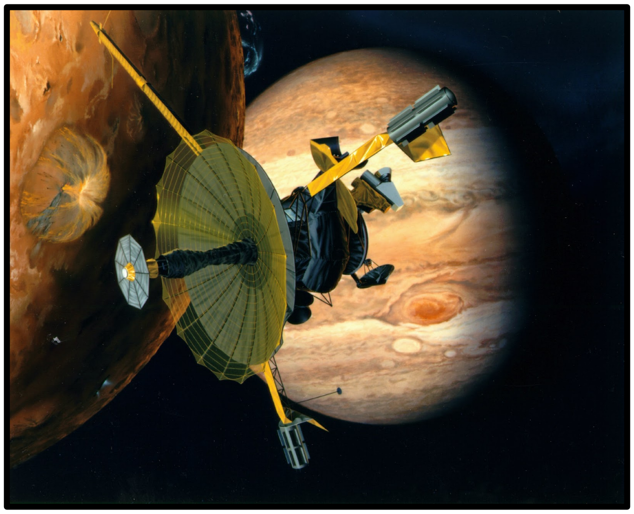
Reel-to-Reel Tape Recorder

Walkie Talkies

Lonnie designed the robot to move using compressed air. When air is compressed, it is pushed into a much smaller space. When the air is released, it pushes back. Lonnie figured out how to use this force to make the robot move. He entered Linex the robot in the Alabama state science fair and won first place!

Lonnie Johnson earned scholarships to Tuskegee University and earned a degree in mechanical engineering. Mechanical engineers design machines and machine parts, similar to what Lonnie had already been doing. Later, he earned a master’s degree in nuclear engineering to follow his interest in how to make use of the energy in atoms or nuclear energy. Johnson’s understanding of nuclear energy led to a job at the Jet Propulsion Laboratory (JPL) in California, which is part of NASA, the National Aeronautics and Space Administration.

At JPL, Johnson was part of the team that developed an atomic battery system for the Galileo spacecraft. Galileo was launched in 1989 and it took six years to travel to Jupiter. The battery system allowed the Galileo spacecraft to send back information about the planet and its moons for 14 years before it quit.



An artist's drawing of the spacecraft Galileo approaching Jupiter

Johnson not only built things at work, he also built things at home. While testing a design for a cooling system that used water and had a tube with a nozzle at one end, Johnson directed the water flow into the bathtub. What came out was a blast of water so powerful that the moving air made the shower curtain fly around. That blast was the beginning of the Super Soaker.

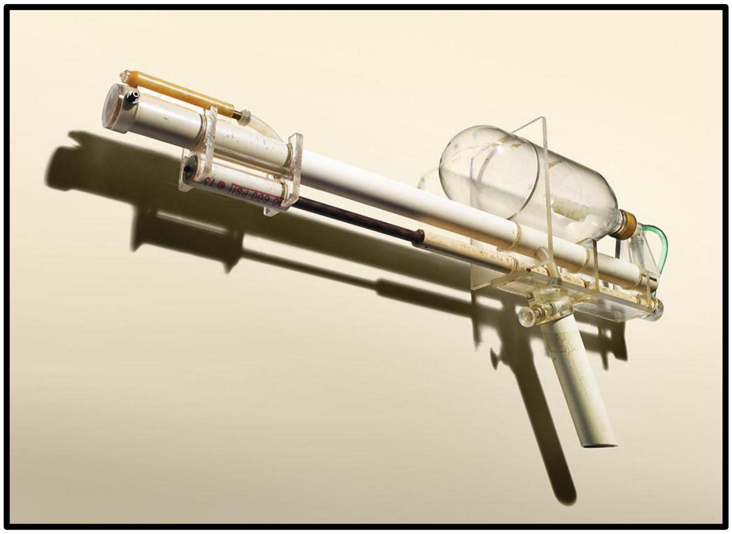
Johnson knew that his system would make a great water squirter. Now he had a different goal and needed to redesign the system for his new purpose: making a water blaster. Engineers need to be clear about the purpose of their design. They also need to use what they know about how related systems work to design their system well.

Johnson knew that water squirters were designed with a small chamber to hold water. His design would use a much larger chamber. Attached to the chamber is a tube to carry the water to a narrow opening where the water is forced out. This would be similar in Johnson's water blaster.

There is a pump in the system for a water squirter, and a trigger is attached to the pump. This is the part where Johnson's design would be the most different. In a simple water squirter, the trigger is first pulled back and it pushes air out of the chamber. Then when the trigger is released, water is drawn into the chamber, and the next time the trigger is squeezed the water is pushed out through the narrow opening. Each single squeeze of the trigger makes a single squirt.

In Johnson's water blaster, the pump would be used to compress air. Each pumping action would push more air into the chamber system, compressing it further, and putting a greater force on the water in the system. After building up the air pressure in the chamber, the trigger would be pulled to release the water, and this would let the air decompress and push water out of the tube with great force.

To test his design idea, Johnson used plastic pipes and an empty soda bottle. He built a prototype, which is a first model. He asked his six-year-old daughter to try it out, and soon all the children in the neighborhood wanted to try it. Johnson knew that he was onto something big.



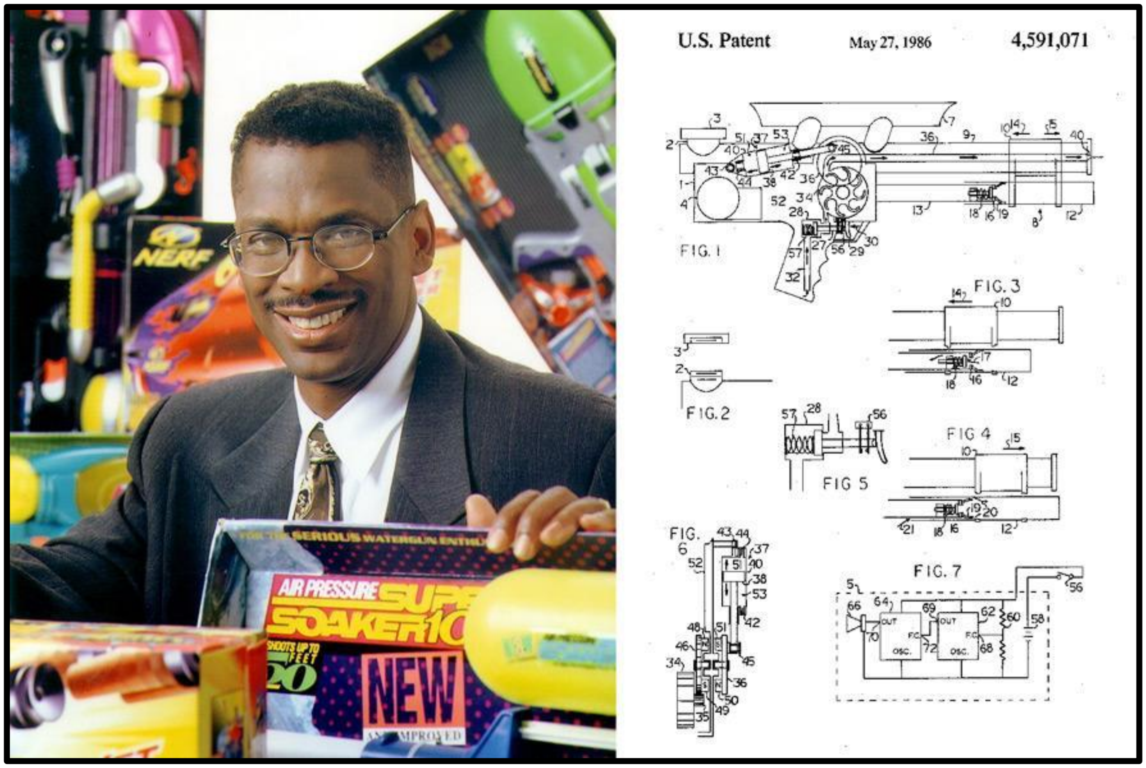
Early prototype of the Super Soaker
The bottle is filled with air. The water is in the long tube.
The water comes out of the shorter tube when the trigger is pulled.

The bathroom blast took place in 1982. Johnson continued working on his water blaster for several more years. Eventually, he found a company that agreed to produce it. The first blaster went on sale late in 1989 and cost $10.00. It was called the Power Drencher. n 1991, that name was changed to Super Soaker. Advertisements included the phrase "Wetter is better," and the product took off.

Johnson and others have continued to work on the design of the Super Soaker. What ideas do you have about how it might be improved? Do you have an idea that would make it easier to use? Are your ideas about how to make the water stream more powerful or travel farther?

Since the 1991 version, there have been more than 100 different models of the Super Soaker. Some models include: Power Soaker Junior Cannon, Super Soaker XP 86 Triple Shot, and Super Soaker Aqua Pack. The aqua pack models have backpacks and hip packs that hold more water reservoirs.

Today Dr. Johnson heads his own company, Johnson Research and Development. There he works with other engineers and scientists to develop new products. Many of those products are designed to allow for more efficient use of energy resources.



Dr. Johnson with different models of the Super Soaker and the 1986 patent illustrations for the original Super Soaker

Image Attributions

Photographs and illustrations of Lonnie Johnson and the Super Soaker - Courtesy Lonnie Johnson

Jukebox by Susanne Nilsson/Flickr

Vintage Electra Portable 4 Transistor Reel-to-reel tape recorder by Joe Haupt/Flickr

Vintage Ross Solid State Walkie Talkie Transceivers by Joe Haupt/Flickr

Galileo probe, lo and Jupiter By NASA - http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=2071 (image link)http://photojournal.jpl.nasa.gov/catalog/PIA18176 (image link), Public Domain, https://commons.wikimedia.org/w/index.php?curid=408298

Appendix D: From Water Squirter to Super Soaker (Unit 2 Interactive Reading Guide)

<table>
<tr><th>Text</th><th>Discussion prompts/Comments</th></tr>
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From Water Squirter to Super Soaker:
How Lonnie George Johnson
Changed Water Games

Not so long ago, on hot days in the summer, children laughed while they chased each other squirting water from small plastic water squirters. Nobody got very wet, but it was a nice way to cool off. All that changed in 1991 when the Super Soaker went on sale. With the Super Soaker, you could drench someone with a single blast of water.

Where did the Super Soaker come from? The story begins in Alabama in the home of Lonnie George Johnson.</td><td></td></tr>
<tr><td>Page 2

Lonnie George Johnson was born on October 6, 1949 in Mobile, Alabama. His mother worked as a nurse's aide and his father worked as a driver at local Air Force bases. Lonnie's father also worked on his car and fixed some things around the house. He and Lonnie worked on projects and built things together.

Lonnie was always curious about how things worked. According to Mrs. Johnson, "Lonnie tore up his sister's baby doll to see what made the eyes close." When he was 13, Lonnie built a go-kart using scrap from junkyards and a lawn mower</td><td>Based on what you have heard so far, how would you describe Lonnie Johnson?</td></tr>
</table>

engine. At this time, Lonnie decided to become an engineer because he realized that "engineers were the people who did the kind of things that I wanted to do."

In high school, Lonnie continued to design and build things. Over a year, he used inexpensive items or parts he found to make a robot he called Linex. Scraps of metal became the robot's body; electronics from an old jukebox and his brothers' walkie-talkies allowed him to control the motion of Linex. Can you tell how he used the reels he got from his sister's tape recorder?


Juke Box


Lonnie Johnson and Linex


Reel-to-Reel Tape Recorder


Walkie Talkies

Have students study the photographs and talk about what they notice.

Lonnie designed the robot to move using compressed air. When air is compressed, it is pushed into a much smaller space. When the air is released, it pushes back. Lonnie figured out how to use this force to make the robot move. He entered Linex the robot in the Alabama state science fair and won first place!

Lonnie's interest in compressed air started in high school and continued throughout his life as you will see.

Demonstration: *Blowing up a balloon*

Tell students that blowing up a balloon is compressing air into a small space. If too much air is blown or pushed into a balloon, you know what will happen. That's important to remember as you learn more about the Super Soaker.

Page 3

Lonnie Johnson earned scholarships to Tuskegee University and earned a degree in mechanical engineering. Mechanical engineers design machines and machine parts, similar to what Lonnie had already been doing. Later, he earned a master's degree in nuclear engineering to follow his interest in how to make use of the energy in atoms or nuclear energy. Johnson's understanding of nuclear energy led to a job at the Jet Propulsion Laboratory (JPL) in California, which is part of NASA, the National Aeronautics and Space Administration.

At JPL, Johnson was part of the team that developed an atomic battery system for the Galileo spacecraft. Galileo was launched

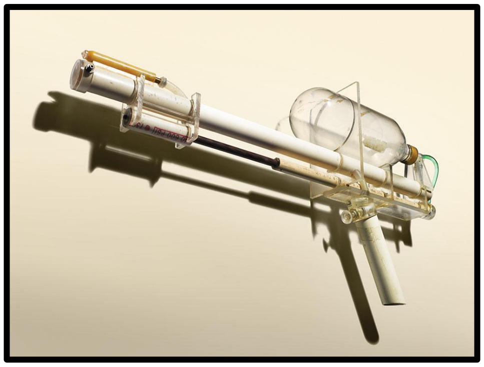
The website for Tuskegee University lists Lonnie Johnson as one of its famous graduates.

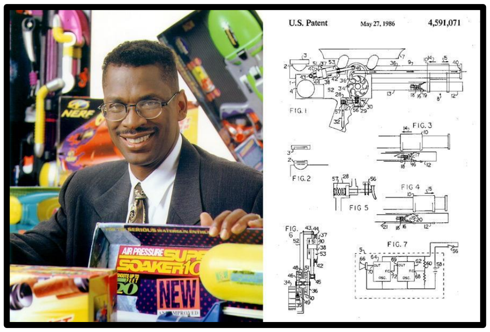
Tuskegee University was founded in 1881 by Booker T. Washington (1856-1915), who was an outstanding African-American educator.

Naming the spacecraft Galileo makes sense because Galileo (1564-1642) was an Italian scientist who was the first person to see Jupiter and three of its moons in 1610.

The first step in an engineering design is identifying the problem. The problem in this case was developing a way to power the Galileo spacecraft. The team knew that the

in 1989 and it took six years to travel to Jupiter. The battery system allowed the Galileo spacecraft to send back information about the planet and its moons for 14 years before it quit.  **An artist's drawing of the spacecraft Galileo approaching Jupiter**	*spacecraft could not be solar-powered, or run on the energy from the sun, because sunlight would be very weak so far from the sun. So they had to develop a different way to solve the problem of powering the spacecraft.* *Tell students that they can access video of the Earth as seen from the International Space Station on the NASA website.* *Space exploration continues even though it is not often in the news.*
Johnson not only built things at work, he also built things at home. While testing a design for a cooling system that used water and had a tube with a nozzle at one end, Johnson directed the water flow into the bathtub. What came out was a blast of water so powerful that the moving air made the shower curtain fly around. That blast was the beginning of the Super Soaker.	*In this case, Johnson was working on an engineering design to solve a problem. He was trying to figure out how to design a cooling system that would use moving water.*
Johnson knew that his system would make a great water squirter. Now he had a different goal and needed to redesign the system for his new purpose: making a water blaster. Engineers need to be clear about the purpose of their design. They also need to use what they know about how related systems work to design their system well.	*Once Johnson saw what his system would do, he set a new goal. Now he wasn't working on a cooling system—he was working on a water blaster.*
Johnson knew that water squirters were designed with a small chamber to hold water. His design would use a much larger chamber. Attached to the chamber is a tube to carry the water to a narrow opening where the water is forced out. This would be similar in Johnson's water blaster.	*Johnson's design process began with studying the water squirter design.* *Show students the water squirter and point out the water chamber, the tube, and the opening where water is forced out.*
Page 4 There is a pump in the system for a water squirter, and a trigger is attached to the pump. This is the part where Johnson's design would be the most different. In a simple water squirter, the trigger is first pulled back and it pushes air out of the chamber. Then when the trigger is released, water is drawn into the chamber, and the next time the trigger is squeezed the water is pushed out through the narrow opening. Each single squeeze of the trigger makes a single squirt.	*Show students the pump in the water squirter and show how it works. Emphasize how the parts work together—trigger, pump, water chamber, opening.* *Demonstrate how the parts all work together.*
In Johnson's water blaster, the pump would be used to compress air. Each pumping action would push more air into the chamber system, compressing it further, and putting a greater force on the water in the system. After building up the air pressure in the chamber, the trigger would be pulled to release the water, and	*Show students the Super Soaker and point out the pump, water chamber, and trigger. Demonstrate how the parts all work together.*

this would let the air decompress and push water out of the tube with great force.	*Explain that when air decompresses, the air is released from its space and pushes out into another space.*
To test his design idea, Johnson used plastic pipes and an empty soda bottle. He built a prototype, which is a first model. He asked his six-year-old daughter to try it out, and soon all the children in the neighborhood wanted to try it. Johnson knew that he was onto something big.	*Here Johnson is using materials that he had or found. What does this remind you of that Johnson did earlier in his life?*
 **Early prototype of the Super Soaker** **The bottle is filled with air. The water is in the long tube. The water comes out of the shorter tube when the trigger is pulled.**	*Have students point to each part of the Super Soaker prototype in the photograph as you read the caption.*
The bathroom blast took place in 1982. Johnson continued working on his water blaster for several more years. Eventually, he found a company that agreed to produce it. The first blaster went on sale late in 1989 and cost $10.00. It was called the Power Drencher. n 1991, that name was changed to Super Soaker. Advertisements included the phrase "Wetter is better," and the product took off.	*Talk with about students the way that the Super Soaker was advertised—how its name and slogan might appeal to them and others like them.*
Page 5 Johnson and others have continued to work on the design of the Super Soaker. What ideas do you have about how it might be improved? Do you have an idea that would make it easier to use? Are your ideas about how to make the water stream more powerful or travel farther?	*What else might make a better Super Soaker besides being easier to use and having a more powerful blast?*
Since the 1991 version, there have been more than 100 different models of the Super Soaker. Some models include: Power Soaker Junior Cannon, Super Soaker XP 86 Triple Shot, and Super Soaker Aqua Pack. The aqua pack models have backpacks and hip packs that hold more water reservoirs.	
Today Dr. Johnson heads his own company, Johnson Research and Development. There he works with other engineers and scientists to develop new products. Many of those products are designed to allow for more efficient use of energy resources.	*Ask students if they would like to be scientists, engineers, or inventors. If so, what might they like to work on?*



Mr. Johnson with different models of the Super Soaker and the 1986 patent illustrations for the original Super Soaker

Mr. Johnson has secured more than 80 patents with 20 still in the process of being granted.

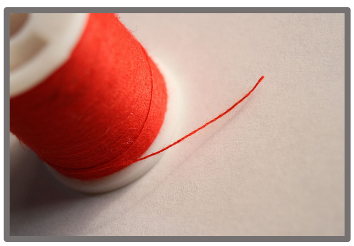
A patent is a license granted by the United State government that gives permission for someone to be the only one who can make something for a certain period of time.

Appendix E: Balloon Rocket Story (Unit 2 Student Text)

Balloon Rocket Story: Part One

Two third graders, Jamal and Maria, who have been reading about how to make toys in their classroom, decided they wanted to build a balloon rocket game for children in their neighborhood. They talked about the materials that they would need, including: a string that will make a track that the balloon will travel along, straws, tape, and balloons. They went to their homes to gather these materials. Here is what they brought with them. What do you notice?

Different thicknesses and textures of string or twine:



Different widths of straws:


Different sizes and shapes of balloons:

Jamal and Maria chose the following:

Twine

Thin Yellow Straw

Medium Round Balloon

Jamal said, "I like the color of this balloon," and Maria said, "I like the thickness of this twine. It's sturdy, so it will easily hold the rocket as it travels." Maria grabbed the yellow straw and they put together their rocket and put it on the twine. Jamal blew up the balloon as much as he could and held the end tightly so that no air could escape. Maria tied the twine to a tree, pulling it as tightly as she could. They watched in anticipation as Jamal let go of the balloon. However, even though they heard the air rush out, the rocket did not travel along the twine.

Jamal and Maria were very surprised! "What did we do wrong?" Jamal asked. "I saw the balloon start to move, but it just seemed to bounce up and down."

Maria said, "Maybe we need a different balloon, one that is bigger."

Jamal asked, "But a bigger balloon would be heavier and harder to move. Why do you think that would work?"

Maria answered, "With a bigger balloon, we could put in more air and that would make a bigger push."

Big Round Balloon

So, they changed the balloon, blew it up as much as they could, and then let go. Again, while they heard lots of air rushing out, the same thing happened; the balloon bounced up and down but did not move forward.

What questions should we ask about the balloon rocket to figure out why the balloon is not moving?

How can we investigate these questions?

Variables are changes in an investigation that could affect the results.

In a "fair test" only one **variable** is changed at a time. What variables are being changed in the examples, below?

Are these fair tests? Why or why not?

- **Race:** Girls vs. boys and give the girls a head start
- **Making basketball shots:** 3rd vs. 4th graders and give the 4th graders a lower basket

What variables could affect Jamal and Maria's results?

What things need to stay the same to make it a "fair test"?

Balloon Rocket Story: Part Two

Along came Auntie Sophie, who is an engineer, walking her dog.

Aunt Sophie: "What are you up to? This looks like fun!"

Jamal: "We are *not* having fun; we are trying to make this game and it's just not working."

Aunt Sophie: "Tell me about it."

So, the children told her about their difficulties.

Aunt Sophie: "When the air came out, what did you notice was happening with your balloon rocket?"

Maria: "The rocket seemed to be stuck. We heard the air from the balloon coming out and we thought it would make the rocket fly. But the balloon just bounced a little. We even tried a bigger balloon so there would be a bigger push from the air leaving the balloon. But it didn't make a difference."

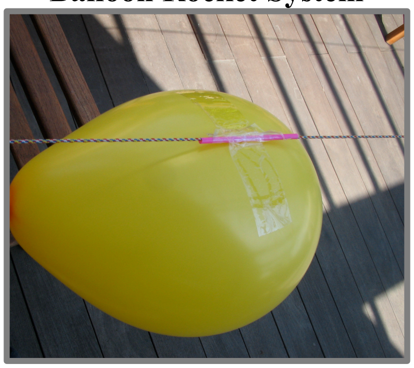
Jamal: "I thought that because the bigger balloon was heavier it wouldn't help, and I was right! The balloon still just bounced up and down."

Aunt Sophie: "You have already thought about a lot of important things; things that a scientist or engineer would think about. They would also think about what the balloon rocket is in contact with. What things are touching one another in your system?"

Jamal: "What do you mean our system? The balloon rocket?"

Aunt Sophie: "Well, you have the balloon attached to a straw to make the rocket, and you have the twine going through the straw and attached to a tree so that there is a track that the balloon rocket can move along. Scientists would call all of these parts together a system."

Balloon Rocket System



Maria: "Cool! We have a system! Okay, so the balloon is touching the straw and the straw is touching the twine. Is that what you mean?"

Aunt Sophie: "Yes. So, you want your system to work, and it doesn't. A scientist or engineer would think about all the parts of the system and which part might need to be adjusted or changed. You already made a change to one part of the system. Which part did you change?"

Jamal: "The balloon! We changed the size."

Aunt Sophie: "Exactly. You told me that change did not get the result you wanted. So, what else could you change?"

Jamal: "The twine!"

Maria: "The straw!"

Aunt Sophie: "Yes, you could change both of those things! What do you think a scientist or engineer would do? Do you think they would change both at once or one at a time?"

Jamal: "Well, I would want to change both to try to make the most difference."

Aunt Sophie: "Scientists *do* think about how they can test something in a way that might make the most difference. But, because they want to know exactly what causes what, they would only change one part of the system at a time. So, we need to talk about *why* you think the balloon rocket isn't moving and make a change to test that idea."

Maria: "We already tried what we thought we needed to change. I thought the force was not enough but more force didn't make it move."

Aunt Sophie: "Do you think there is *anything* you can do to make the balloon rocket move?"

Jamal: "I can push it."

Maria: "But it's supposed to move from the air coming out of the balloon."

Aunt Sophia: "Right. But it's okay first to just think about getting it to move. Try it, Jamal."

Jamal pushed the rocket with his hand.

Jamal: "I can move it but it doesn't move easily."

Maria pushed the rocket as well.

Aunt Sophie: "So let's do a thought experiment. Let's imagine that I had a large and heavy box sitting on the sidewalk, and let's say that I pushed it and it didn't move. What would you think about that?"

Maria: "If the box is heavy, you may not be strong enough to get it to move. I know that it's hard to push something heavy. But, the balloon rocket isn't heavy."

Aunt Sophie: "You are right, but remember that we have to think about the *whole* system. With the box, what do you think would happen if there was ice on the sidewalk that made it smooth, and then I pushed the box? Do you think it would move?"

Maria: "I bet it would go flying! Like one time when the driveway was frozen over, Jermaine and I pushed his little brother Nicky back and forth across the ice and he slid like he was riding a skateboard. He said it was so much fun that he did not want us to stop, but we got tired."

Aunt Sophie: "That's an excellent connection. You actually had an experience like our thought experiment! So, the box moves when I push it on an icy sidewalk but not when the sidewalk is bare. This difference is due to a concept that scientists call *friction*. When an object is moving, there will be friction between it and the surface it is in contact with. My box was in contact with the sidewalk or the ice. What is your balloon rocket in contact with?"

Jamal and Maria: "The twine!"

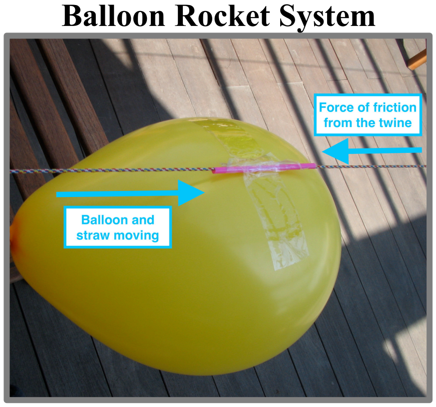
Aunt Sophie: "Exactly. The twine is like the sidewalk in our thought experiment. There is friction between the twine and the straw when the balloon rocket moves. And for scientists and engineers, friction is a force. It is a force that stops or changes the direction of motion. It is a push that occurs in the opposite direction of the motion of the moving object that stops it or slows it down."

Jamal: "Wait. But I thought a force was a push or pull. How can friction be a force? Where is the push or the pull?"

Maria: "Yeah, how can the twine be a force?"

Aunt Sophie: "These are such good questions, you two. For now, let's just say that friction is a force that is generally *opposite* to the motion of an object, and at levels that we can't see, it can be like a pull or a push that works against the motion. Can you live with that explanation?"

Balloon Rocket System



Maria: "I can live with that."

Jamal: "Me too."

Aunt Sophie: "So, let's think about what you can do with the friction in your balloon rocket system. What are your thoughts about how to make less friction so that your balloon rocket works?"

Aunt Sophie, Jamal, and Maria talked about how they could change the system to investigate how the force of friction in their balloon rocket system affects the motion of the balloon rocket.

What do you think?

Image Attributions

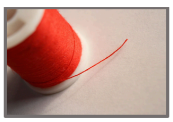
Appendix F: Balloon Rocket Story (Unit 2 Interactive Reading Guide)

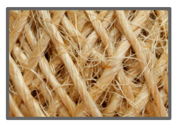
<table>
<tr><th>Text</th><th>Guide</th></tr>
<tr><td>

Balloon Rocket Story: Part One

Two third graders, Jamal and Maria, who have been reading about how to make toys in their classroom, decided they wanted to build a balloon rocket game for children in their neighborhood. They talked about the materials that they would need, including: a string that will make a track that the balloon will travel along, straws, tape, and balloons. They went to their homes to gather these materials. Here is what they brought with them. What do you notice?

Different thicknesses and textures of string or twine:





Different widths of straws:


Different sizes and shapes of balloons:

</td><td>

Following the reading of this paragraph: The class can discuss what they notice about the assorted materials, sharing their thinking about how, for example, the size of the balloon, the width of the straw, the characteristics of the material for the track, and the mass of the decorations might affect the working of the balloon rocket.

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Jamal and Maria chose the following:

Twine

Thin Yellow Straw

Medium Round Balloon

Jamal said, “I like the color of this balloon,” and Maria said, “I like the thickness of this twine. It’s sturdy, so it will easily hold the rocket as it travels.” Maria grabbed the yellow straw and they put together their rocket and put it on the twine. Jamal blew up the balloon as much as he could and held the end tightly so that no air could escape. Maria tied the twine to a tree, pulling it as tightly as she could. They watched in anticipation as Jamal let go of the balloon. However, even though they heard the air rush out, the rocket did not travel along the twine.

</td><td>

Following the reading of this paragraph: The children can be invited to say, in their own words, what happened in this part of the story.

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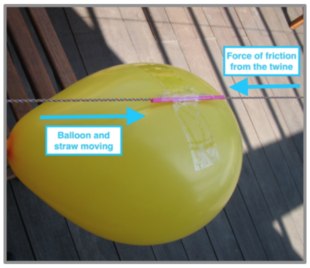
Jamal and Maria were very surprised! "What did we do wrong?" Jamal asked. "I saw the balloon start to move, but it just seemed to bounce up and down."	The class can discuss their ideas about what might have happened, and what they would recommend Jamal and Maria do.
Maria said, "Maybe we need a different balloon, one that is bigger." Jamal asked, "But a bigger balloon would be heavier and harder to move. Why do you think that would work?" Maria answered, "With a bigger balloon, we could put in more air and that would make a bigger push." **Big Round Balloon** 	Discuss the solution that Maria has suggested and Jamal's thinking about that solution. Connect back to previous demonstrations of the balloon rocket. Ask students what questions they had about how the balloon rocket moved or what their ideas were for making it work better.
So, they changed the balloon, blew it up as much as they could, and then let go. Again, while they heard lots of air rushing out, the same thing happened; the balloon bounced up and down, but did not move forward. **What questions should we ask about the balloon rocket to figure out why the balloon is not moving?** **How can we investigate these questions?** **Variables** are changes in an investigation that could affect the results. In a "fair test" only one **variable** is changed at a time. What variables are being changed in the examples, below? Are these fair tests? Why or why not? • **Race:** Girls vs. boys and give the girls a head start • **Making basketball shots:** 3rd vs. 4th graders and give the 4th graders a lower basket   **What variables could affect Jamal and Maria's results?** **What things need to stay the same to make it a "fair test"?**	After reading this paragraph: Demonstrate the rocket set up similar to the one of Maria and Jamal (see lesson plan describing teacher-led investigation) The children can be encouraged to identify all the parts of the balloon rocket system. Ask students what questions should Maria and Jamal should ask about the parts of the balloon rocket to figure out why it is not moving. They will then be able to compare their thinking with the analysis that Maria and Jamal do of the system in Part Two.

Balloon Rocket Story: Part Two Along came Auntie Sophie, who is an engineer, walking her dog. **Aunt Sophie:** "What are you up to? This looks like fun!" **Jamal:** "We are *not* having fun; we are trying to make this game and it's just not working." **Aunt Sophie:** "Tell me about it." So, the children told her about their difficulties. **Aunt Sophie:** "When the air came out, what did you notice was happening with your balloon rocket?" **Maria:** "The rocket seemed to be stuck. We heard the air from the balloon coming out and we thought it would make the rocket fly. But the balloon just bounced a little. We even tried a bigger balloon so there would be a bigger push from the air leaving the balloon. But it didn't make a difference." **Jamal:** "I thought that because the bigger balloon was heavier it wouldn't help, and I was right! The balloon still just bounced up and down." **Aunt Sophie:** "You have already thought about a lot of important things; things that a scientist or engineer would think about. They would also think about what the balloon rocket is in contact with. What things are touching one another in your system?"	After reading the first sentence of this exchange, ask students the following questions: What things do you think scientists or engineers would think about? What might they have questions about?
Jamal: "What do you mean our 'system?' The balloon rocket?" **Aunt Sophie:** "Well, you have the balloon attached to a straw to make the rocket, and you have the twine going through the straw and attached to a tree so that there is a track that the balloon rocket can move along. Scientists would call all of these parts together a system." **Balloon Rocket System**  **Maria:** "Cool! We have a system! Okay, so the balloon is touching the straw and the straw is touching the twine. Is that what you mean?" **Aunt Sophie:** "Yes. So, you want your system to work, and it doesn't. A scientist or engineer would think about all the parts of the system	Before reading the next section, ask students what they think Aunt Sophie means when she says the balloon rocket is a "system"? Ask students to give examples of systems they know about. Students may talk about body systems, the solar system, and ecosystem, etc. You may choose to add the word systems to the word wall.

and which part might need to be adjusted or changed. You already made a change to one part of the system. Which part did you change?”	
Jamal: “The balloon! We changed the size.” **Aunt Sophie:** “Exactly. You told me that change did not get the result you wanted. So, what else could you change?” **Jamal:** “The twine!” **Maria:** “The straw!” **Aunt Sophie:** “Yes, you could change both of those things! What do you think a scientist or engineer would do? Do you think they would change both at once or one at a time?” **Jamal:** “Well, I would want to change both to try to make the most difference.”	After reading this section: Ask students what variables Jamal and Maria want to change (if the term *variable* is on the word wall, point it out there). The students can discuss what they think of Jamal’s suggestion to change both the twine and the straw to “make the most difference.” What do the students think Aunt Sophie is going to suggest?
Aunt Sophie: “Scientists <u>do</u> think about how they can test something in a way that might make the most difference. But, because they want to know exactly what causes what, they would only change one part of the system at a time. So, we need to talk about <u>why</u> you think that balloon rocket isn’t moving and make a change to test that idea.” **Maria:** “We already tried what we thought we needed to change. I thought the force was not enough but more force didn’t make it move.” **Aunt Sophie:** “Do you think there is *anything* you can do to make the balloon rocket move?” **Jamal:** “I can push it.” **Maria:** “But it’s supposed to move from the air coming out of the balloon.” **Aunt Sophia:** “Right. But it’s okay first to just think about getting it to move. Try it, Jamal.” Jamal pushed the rocket with his hand.	
Jamal: “I can move it but it doesn’t move easily.” Maria pushed the rocket as well. **Aunt Sophie:** “So let’s do a thought experiment. Let’s imagine that I had a large and heavy box sitting on the sidewalk, and let’s say that I pushed it and it didn’t move. What would you think about that?”	After reading this paragraph, ask the students what they think the box represents in the thought experiment that Aunt Sophie suggests.

 **Maria:** "If the box is heavy, you may not be strong enough to get it to move. I know that it's hard to push something heavy. But, the balloon rocket isn't heavy."	
Aunt Sophie: "You are right, but remember that we have to think about the *whole* system. With the box, what do you think would happen if there was ice on the sidewalk that made it smooth, and then I pushed the box? Do you think it would move?" **Maria:** "I bet it would go flying! Like one time when the driveway was frozen over, Jermaine and I pushed his little brother Nicky back and forth across the ice and he slid like he was riding a skateboard. He said it was so much fun that he did not want us to stop, but we got tired." **Aunt Sophie:** "That's an excellent connection. You actually had an experience like our thought experiment! So, the box moves when I push it on an icy sidewalk but not when the sidewalk is bare. This difference is due to a concept that scientists call *friction*. When an object is moving, there will be friction between it and the surface it is in contact with. My box was in contact with the sidewalk or the ice. What is your balloon rocket in contact with?"	After reading this paragraph, the students can discuss experiences they have had with different surfaces and how the surface makes a difference in the ease with which you can push or pull something across it (examples could include, smooth versus rough carpet, glass vs. bumpy stone, slippery gym shoes when they get smooth on the bottom). Invite the students to answer Aunt Sophie's question: What is the balloon rocket in contact with?
Jamal and Maria: "The twine!" **Aunt Sophie:** "Exactly. The twine is like the sidewalk in our thought experiment. There is friction between the twine and the straw when the balloon rocket moves. And for scientists and engineers, friction is a force. It is a force that stops or changes the direction of motion. It is a push that occurs in the opposite direction of the motion of the moving object that stops it or slows it down." **Jamal:** "Wait. But I thought a force was a push or pull. How can friction be a force? Where is the push or the pull?" **Maria:** "Yeah, how can the twine be a force?"	After reading this paragraph, the class can linger on the idea of friction, adding this word to the interactive word wall, including the definition (i.e., "friction describes a force that occurs between objects when one tries to move over the other. It is a push that occurs in the opposite direction of the motion of the object to stop or slow it down.") and adding examples of times when they have experienced the force of friction. At this point, the students can experience how using powder (like talc) can reduce friction when the children rub their hands together. Invite the students to: rub their hands together, describe what they feel, and then sprinkle a bit of powder on one of their hands, and after their rubbing their hands again, describe what they feel; how is it the same as how is it different? Give one student a pair of rubber gloves and ask them to try to rub their hands together. Ask them to describe what they feel; how is it the same as how is it

	different? Was the friction increased or decreased?
Aunt Sophie: "These are such good questions, you two. For now, let's just say that friction is a force that is generally *opposite* to the motion of an object, and at levels that we can't see, it can be like a pull or a push that works against the motion. Can you live with that explanation?  **Maria:** "I can live with that." **Jamal:** "Me too." **Aunt Sophie:** "So, let's think about what you can do with the friction in your balloon rocket system. What are your thoughts about how to reduce the friction so that your balloon rocket works?" Aunt Sophie and Jamal and Maria talk about how they can change the system to investigate how the force of friction in their balloon rocket system affects the motion of the balloon rocket. **What do you think?**	The class can then discuss what Jamal and Maria might change about the bottle rocket system to change the amount of friction in the system (e.g., add powder to the straw, use a smoother/smaller string, use a bigger straw).

Appendix G: In the Garden with Dr. Carver (Unit 4 Interactive Reading Guide)

Reading guide for *In the Garden with Dr. Carver*
written by Susan Grigsby and illustrated by Nicole Tadgell

For the teacher:
This is a lovely book that tells about some of the many contributions Dr. George Washington Carver made to plant science. Dr. Carver was born into slavery. Slavery was abolished when Dr. Carver was a young boy and he was raised in Missouri by the man who paid for George and his family, as well as the man's wife. George, in fact, gets his last name, Carver, from this man. The Carvers saw to George's education. He attended all-Black schools because Black people were not permitted to be educated with White people at that time. George was an excellent student and went to college after finishing high school. He was the first Black student to study at Iowa State Agricultural College, where he completed his Bachelor's and Master's Degrees in plant science. He became the first Black faculty member at Iowa State. Dr. Carver was then invited to teach at The Tuskegee Institute. The children may remember that the NASA engineer, Lonnie Johnson, studied at the Tuskegee Institute (but Dr. Carver had died before Lonnie Johnson was a student there). At the institute, Dr. Carver conducted a number of experiments for the purpose of exploring how to improve the health of plants, get more crop yield, and use peanut (and other) crops to produce a variety of foods. This book recounts how Dr. Carver used his knowledge to educate farmers across the country.

One way that you may use this book with your students is to support their initial brainstorming/planning of their mung bean investigations. For instance, on the page that begins, "**But for me, the best part of Dr. Carver's visit was**…," Dr. Carver asks the children in the book why they think one of the rose bushes is growing poorly while the other is growing well. After reading this portion and showing the illustration, you may ask students what they notice about the differences in the environmental conditions of the two rose bushes. Your students will notice that the rose bush that is growing poorly, does not receive sunlight, while the other bush does. You may record this as one environmental condition students might investigate using the mung beans: *How does the amount of light affect how mung beans grow?*

Additionally, on the page that begins, "**After our feast, Dr. Carver said that it was time to plant our own kitchen garden**…" Dr. Carver and the children in the book consider a location, with dry, rocky soil to plant a garden. Here, you might ask students again what environmental condition this suggests they might investigate while growing the mung beans. The question recorded her would be: *How does the type of soil affect how mung beans grow?*

Here are a few additional ideas for supporting your students to discuss the ideas in this text.

Text:
The adults all gather around, eager for advice…
You might ask why Dr. Carver compared cotton to "a hungry monster" and what problem he wanted to solve?

Text:
He was even teaching…
After reading this paragraph, discuss what the author means when she writes, "he (Dr. Carver) was even teaching people how to turn simple foods like peanuts and sweet potatoes into luxuries like coffee, butter, and sugar."

[The author is not being literal in this case…rather, the author is pointing out that Dr. Carver figured out how to use the plants that farmers could grow on their lands to make many products which could then be sold. From the money farmers got from these sales, they could buy luxuries like coffee, butter, and sugar.]

Text:
But for me, the best part of Dr. Carver's visit was…
The students can discuss what Dr. Carver meant when he said to Sally, "Listen to the plants and they will tell you what they need." The students can then discuss ways in which they have been "listening to plants" as they observe their seeds growing.

At this point in the text, you can encourage your students to look closely at the two rose bushes and observe what is different about where they are growing. Your students will likely notice the difference in the light source available to each rose bush. On the next page, the character affirms that one important difference in the amount of light available to the two rose bushes.

The students can discuss the observation that Sally made that led Dr. Carver to exclaim that she did "an excellent job of observation."

Text:
My brother Ben found a big web…
The students can discuss why Dr. Carver stopped Ben from killing the spider and what he meant when he suggested that "the plants, the soil, and the animals that visit are all connected, just like a web."

Text:
In every single flowerbed…
The students can discuss the role that the wind played in spreading the dandelions.

Text:
A plant is a weed if it's growing uninvited…
Before reading this part of the text, the students can talk about their own definitions for the word, "weed." Collect a few definitions and then read Dr. Carver's definition: "a weed is a plant that is growing but has not been invited." The students can compare this interesting definition of a weed with their own definitions.

The students can discuss why the dandelion weeds were a problem in this case.

Text:
After our feast, Dr. Carver said…
The class can discuss what Dr. Carver meant when he said, "Nothing ever will (grow in the land behind the school), unless we improve this worn-out land. Plants, like people, need nutritious food to help them grow."

Text:
Dr. Carver took us to a patch of forest…
The class can discuss where Dr. Carver suggested the class could find the nutritious food that would help their garden grow and what Dr. Carver's "recipe" for compost was.

Some of the children may have compost piles of their own. If so, the class can discuss what "ingredients" they use in their own compost piles.

Text:
Some people come in and out of your life…
The students can discuss how the author tells us how the narrator of this story, Sally, felt about Dr. Carver's visit to her school.

Appendix H: Ms. Ollie's Plant Investigation (Unit 4 Student Text)

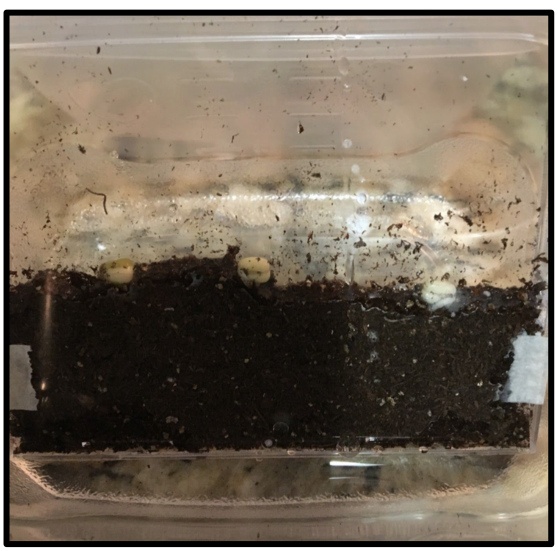
Ms. Ollie's Plant Investigation

Part I: Planning the Investigation

Ms. Ollie, a third-grade teacher, emerged from the back room, holding two clear plastic CD cases. Ms. Ollie's third grade class quickly noticed that these weren't just *any* CD cases; through the clear plastic, the students saw that the cases were each half filled with dark brown soil, with three tiny seeds resting on top. Like us, Ms. Ollie's students have been studying how plants grow and what plants need to survive in their environment.

Ms. Ollie asked her class to gather around the table to look at the plants and to describe what they noticed.

Here is what they saw:



"They look the same," Maci said.

"The seeds are white, but some of them are covered with soil, so they are hard to see," Antwon added.

"They have little sprouts," Levi noted.

Ms. Ollie asked them to look closely at the soil and tell her about it.

"The soil is moist, and it's dark brown," Mia observed.

"Some of the soil is stuck to the side of the case and there are three seeds in each case," Tara said.

Ms. Ollie asked her students what they should do with these seeds to figure out how different parts of the environment affect how plants grow. Antwon suggested that the class could put one plant in a sunny spot and the other one somewhere dark.

Look closely at the photograph of Ms. Ollie's classroom.
Can you recommend two locations in the classroom that fit Antwon's suggestion?
Explain why you think these would be good choices.

Maci agreed with Antwon and said that putting one plant in the windowsill and one under the table would help them figure out how much sunlight the plants need to grow.

"The CD case on the windowsill will get lots of sunlight, especially on sunny days. The one under the table won't get much sunlight at all," said Maci.

Ms. Johnson summarized, "So Maci and Antwon think that we should investigate the amount of light the plants receive. Does everyone agree?" Several students raised their hands. Many students agreed, but Levi had another idea.

"My grandma has a garden and we have to water it all summer! If we don't, she says that all of the plants will turn brown and stop growing, so I think plants need water too!" exclaimed Levi.

"This is an interesting idea," said Ms. Johnson. "What do you think we should do, Levi?"

Levi continued, "I think we need to water the seeds on the windowsill a little every day, but we shouldn't give any water to the seeds under the table. Then, we can see what happens when one plant gets water *and* light, but the other one doesn't."

Ms. Ollie continued to talk with her class about planning their plant investigation.

Think about the investigation idea that Levi suggested. He said they should change the amount of light and the amount of water the plants received, so the class could figure out how these variables affect how the seeds grow. Is this a fair test?

How could you help Ms. Ollie's class design a fair test to investigate the amount of light plants need to grow? (What variable should they change? What variables should they keep the same?)

What would you need to do if you also wanted to investigate how the amount of water affected plant growth?

Part II: Making Observations and Analyzing Data

After learning about how to plan a fair test, Ms. Ollie's class decided that first, they would investigate sunlight and give both plants the same amount of water. This way, they could make sure their test was fair and they could make claims about how the amount of light affected their plants. After they observed plant growth, measured the size of the stems and leaves, and recorded their observations, they would conduct a second investigation to figure out how the amount of water affects plants.

After seven days, Ms. Ollie brought the plants back to the table and invited the class to describe them again.

This is what they saw:

Ms. Ollie's students were surprised by what they observed. "What do you notice?" Ms. Ollie asked.

"The mung bean plants growing under the table with no light are much taller than the ones growing on the windowsill!" Jeremy said.

Hanna added, "The plants from the windowsill are short but are colorful. They have green and red on them. The ones from under the table are just white and yellow."

Ms. Ollie said the class should measure and record their observations in a data table, and then would observe the two plants again the next week.

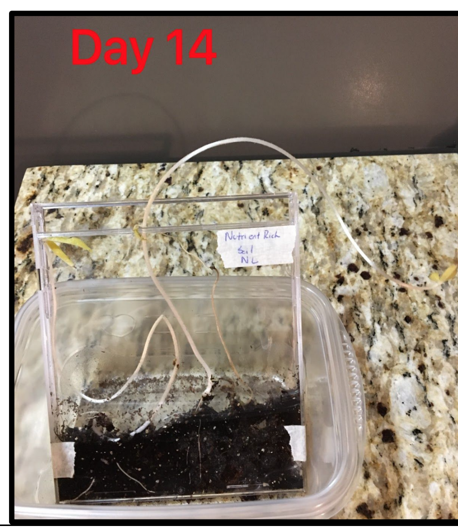
Here is their Day 7 data table:

What do you notice?

Day 7 Observations			
Amount of Light	**Stem Height**	**Color**	**Leaf Size**
Full Sunlight (windowsill)	***Plant 1:*** ½ inch ***Plant 2:*** 1 inch ***Plant 3:*** 1 inch	Red stems Bright green leaves	***Plant 1:*** ½ inch ***Plant 2:*** ½ inch ***Plant 3:*** ½ inch
No Sunlight (under table)	***Plant 1:*** 1 ½ inches ***Plant 2:*** 3 ½ inches ***Plant 3:*** 2 inches	White stems Yellow leaves	***Plant 1:*** ½ inch ***Plant 2:*** ½ inch ***Plant 3:*** ½ inch

Seven days later, Ms. Ollie's class observed their plants again.

This is what they saw:



"The plants changed a lot since last week!" Maci observed.

"The plants from the windowsill are still bright red and green, and the ones from under the table are still white and yellow," Brian said.

Ms. Ollie gave her students a few more minutes to record their observations and then asked again what they noticed.

Hanna said, "The plants from the windowsill have grown a lot and their leaves are huge now!"

"The white stems are still longer, but look how droopy they are!" Levi exclaimed.

What other observations can you make about these plants?

Here is their Day 14 data table:

What do you notice?

Day 14 Observations			
Amount of Light	**Stem Height and Shape**	**Color**	**Leaf Size**
Full Sunlight (windowsill)	***Plant 1:*** 2 ½ inches (standing) ***Plant 2:*** 3 ½ inches (standing) ***Plant 3:*** 3 inches (standing)	Red and green stems Bright green leaves	***Plant 1:*** 1 inch ***Plant 2:*** 1 ½ inches ***Plant 3:*** 1 ½ inches
No Sunlight (under table)	***Plant 1:*** 5 inches (bent) ***Plant 2:*** 7 inches (falling over) ***Plant 3:*** 3 inches (leaning)	White and brown stems Yellow and brown leaves	***Plant 1:*** ½ inch ***Plant 2:*** ½ inch ***Plant 3:*** ¼ inch

Part III: Making Claims

After they made their final observations, Ms. Ollie told her class they could use their data to make claims to answer their investigation question: *How does the amount of light affect the growth of plants?* Ms. Ollie asked, "Based on your data, how would you answer this question?"

Michelle raised her hand, "I think the plants with no sunlight grew best because they were always the tallest. The last time we measured, one of the plants from under the table was 7 inches tall. None of the plants from the windowsill were even close!"

Some of Michelle's classmates agreed, but not everyone. Antwon didn't think the stem height was the best data to help them answer the investigation question. "But look at the two plants," said Antwon. "The ones growing under the table don't look healthy at all. Healthy plants are colorful and stand up tall. They have big leaves like our plants growing in the windowsill.

The plants under the table are yellow, brown, and droopy. I don't think they are growing well at all."

Look back at the Day 14 data table and photographs. *Turn-and-talk* to a partner: Which claim do you agree with? What is your evidence?

After Ms. Ollie's class made a claim to answer their investigation question about the amount of light their plants needed to grow, they conducted another investigation to figure out how the amount of water affected the growth of plants.

You have also been investigating how different parts of the environment affect how plants grow in your class.

What variables have you been investigating?

What did you figure out in your investigations?

Ms. Ollie's class found that their plants were healthier when they were placed in environments with full sunlight and were given daily water. However, many of Ms. Ollie's students still had questions about *why* their plants needed things like light and water to grow well. Read on to figure out *why* plants need certain things from the environment.

Part IV: Putting the Pieces Together

When you look at the plants growing around your school, community, and classroom, what do you notice? You might notice different parts of these plants like their stems, leaves, roots, and flowers. Plants come in many different shapes and sizes, but do you know what causes plants to grow?

From the mung bean investigations that you conducted in class and the investigations that you read about, you figured out that plants need certain things to grow. To grow well, almost all plants need light, water, and air. Think about observing the roots of your mung beans as they grew. The mung beans were using their roots to absorb, or take in, the water you provided for your plants.

Now, think about your plants and Ms. Ollie's plants growing on the windowsill, where they received plenty of sunlight. Did you notice how much larger the leaves were on the plants placed in the sunlight than those that were growing in the dark? Think about the plants that were growing in dark. Their stems grew tall, reaching for light, but because there was no light, the leaves stayed small and yellow while the stems grew white and bent over. Plants use their leaves to absorb or take in sunlight, as well as carbon dioxide from the air. Both light and air help plants grow tall and healthy. Scientists call this process, through which plants use light, water, and air to grow, photosynthesis.

Another important part of the environment for many plants is soil. Think about how the roots of your mung beans spread throughout the soil. The roots acted like an anchor to help your plants grow upward from the soil. Your soil also held in the moisture or water your plants needed to grow. Finally, your mung beans were using their roots to absorb or take in nutrients from the soil.

All of these parts of the environment - light, water, air, and soil - work together to help plants grow roots, stems, leaves, and flowers. As you continue to grow plants and figure out how to grow plants for food in your community, observe your plants closely so you can figure out if they are getting everything they need to grow well.

Image Attributions

Classroom window with aquarium and plants By Jessica/Flickr

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