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Sixth-Grade Elementary and Seventh- and Eighth-Grade Middle School Teachers' Knowledge and Beliefs About Science Literacy

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ABSTRACT

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The purpose of this qualitative study was to explore Grades 6-8 teachers' knowledge and beliefs about science literacy and instruction that develops science literacy, in both the fundamental and derived senses. All Grade 6 elementary teachers and Grades 7-8 middle school science teachers from five school districts in the Mountain West region of the U.S. were invited to participate by responding to an online survey consisting of open response questions and critical instances. Data were analyzed using an immersion style of coding. Findings suggest a majority of teachers view literacy as reading and writing and text as something that is read or written. Teachers described science literacy as either the integration of science and literacy or as using basic literacy skills in science. When teachers were asked to identify quality instruction for developing science literacy via critical instances, a majority were successful when presented with examples that exemplify best practices in teaching science literacy but could not discriminate levels of quality when examples included minimal or no elements considered to be best practices. This suggests that teacher education programs and professional development should include opportunities that help preservice and practicing teachers better understand the importance of teaching both science subject matter knowledge as well as communicative practices used in science.

Keywords: disciplinary literacy, elementary, middle school, science education, science literacy

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CHAPTER 1

Introduction

The terms and circumstances of human existence can be expected to change radically during the next human life span. Science, mathematics, and technology will be at the center of that change—causing it, shaping it, responding to it. Therefore, they will be essential to the education of today's children for tomorrow's world. (American Association for the Advancement of Science [AAAS], 1993, p. xi)

Although this statement was written over 20 years ago, it could have been written decades earlier. In the aftermath of WWII and with the 1957 launch of Sputnik by the Soviet Union, the people of the United States felt pressure to compete at a global level in science, mathematics, and technology for both national security and economic prosperity (DeBeor, 1991; Duschl, 1990; Yee & Kirst, 1994).

Since then, global competitiveness has been a continual concern. U.S. presidents, organizations, businesses, and government reports have all emphasized the need to prepare K-12 students with the skills and knowledge required to enter jobs that may not yet exist (AAAS, 1993; Achieve, Inc., 2015; Carnegie Corporation of New York-Institute for Advanced Study Commission on Mathematics and Science Education Executive Summary, 2009; Kuenzi, 2008; New York State Archives, n.d.; Partnership for 21st Century Learning, 2015; White House Office of Science and Technology Policy, 2014). For this reason, and because "science, engineering, and the technologies they influence permeate every aspect of modern life" (National Research Council [NRC], 2012, p. 7), K-12 students need an education that promotes specific knowledge and skills in science, technology, engineering, and mathematics (STEM) as a foundation to enter a workforce that is constantly evolving, even as the world becomes more interconnected.

Although the push to increase student learning in science, mathematics, and technology has been a persistent national consideration since the 1950s, the desired outcomes have evolved somewhat over time. The fervor toward improving science education during the Sputnik era was aimed at "producing more American engineers and scientists" (Moyer & Everett, 2012, p. 4). Thirty years later, with the publication of *Science for All Americans: Project 2061* (AAAS, 1990), the educational emphasis had shifted to preparing *all* students with the knowledge and skills necessary to participate as educated adult members of society. The goal was to promote "literacy in science, mathematics, and technology in order to help people live interesting, responsible, and productive lives" (AAAS, 1993, para. 4). More recently, Bybee (2010) re-emphasized the goal of science for all, adding:

> The United States needs a broader, more coordinated strategy for precollege education in science, technology, engineering and mathematics (STEM). This strategy should…address STEM professions, for a workforce with deep technical and personal skills, and for a STEM-literate citizenry prepared to address the grand challenges of the 21st century. (p. 996)

This statement represents the most current focus of change efforts in K-12 education: to prepare students not just to live interesting, responsible, and productive lives, but to be college and career ready with the requisite knowledge and skills to be successful in a competitive global economy and to be able to solve increasingly complex problems of the future (National Governors Association Center for Best Practices [NGA] & Council of Chief State School Officers [CCSSO], 2010; Next Generation Science Standards [NGSS], NGSS Lead States, 2013).

In recent years, these new goals have been articulated in national standards developed across three academic disciplines. First, the *Common Core State Standards for English*

Language Arts (NGA & CCSSO, 2010) communicate developmental benchmarks for students in reading, writing, speaking and listening, and language (e.g., conventions, knowledge of language, vocabulary acquisition and use, fluency, decoding). An additional section has also been included for Grades 6-12 that includes *Literacy in History/Social studies, Science, and Technical Subjects*. Second, the *Common Core State Standards for Mathematics* (NGA & CCSSO, 2010) include standards in mathematics for Grades K-8 and strand type for Grades 9-12 (i.e., algebra, functions, number and quantity, geometry, statistics and probability). Finally, the *Next Generation Science Standards (*NGSS Lead States, 2013) describe the foundational knowledge and skills students will need to be able to eventually enter careers in science, technology, and engineering if they choose, and "to engage with the major public policy issues of today as well as to make informed everyday decisions" (National Research Council [NRC], 2012, p. 7). In order to do so, various dimensions of science and engineering are included, including a specific focus on learning to communicate (i.e., speak, listen, read, write) in discipline appropriate ways both in science and in engineering. It is important to note that even though these three new standards documents specifically emphasize different content areas, when taught and learned in combination, they are designed to work together to help "make STEM literacy a reality for all students" (Bybee, 2010, p. 996).

This study focuses specifically on science and literacy and the relationship between them in developing what Shanahan and Shanahan (2008; 2012) have referred to as *disciplinary literacy*, the ability to read, interpret, and produce the type of text used in a specific discipline, combined with the acquisition of core content knowledge and practices in that discipline (NRC, 2012). In science, this is referred to as science literacy (Hand et al., 2003), or scientific literacy (Norris & Phillips, 2003). Although K-12 students are not expected to attain science literacy at the same level as scientists, the new standards suggest they should work toward developing science literacy and that teachers have a direct and influential role in providing access to these skills and knowledge through classroom instruction (Bybee, 1993; NRC, 2012). Interestingly, although much has been written about what science literacy should entail (e.g., NRC, 1996, 2012; Norris & Phillips, 2003), little research has investigated practicing teachers' conceptions of what it should involve at different grade levels, despite a large body of longstanding research that documents the importance of teachers' beliefs and knowledge in shaping their instructional decisions (e.g., Gess-Newsome, 1999; Gregoire, 2003; Laplante, 1997; Smith & Southerland, 2007; Thompson, 1992). This insight holds potential to inform both teacher preparation and ongoing professional development efforts to support prospective and practicing teachers as they adjust current curricula and instruction to better prepare children to meet the new standards and to participate in an increasingly competitive and international society (van Driel & Verloop, 2002).

Given the need for a better understanding of what teachers know and believe about science literacy and the influence these conceptions have on what happens in classrooms (Bryan, 2012; Jones & Leagon, 2014), the overall purpose of this descriptive qualitative study was to explore sixth-, seventh-, and eighth-grade teachers' knowledge and beliefs about science literacy. More specifically, the goal was to examine how these teachers define it and what they perceive that it should look like during instruction. With this purpose in mind, the research questions that guided this study were the following:

1. How do sixth-, seventh-, and eighth-grade teachers describe science literacy or disciplinary literacy in science?

2. How do sixth-, seventh-, and eighth-grade teachers differ in their knowledge and beliefs about science literacy?
3. What do these teachers consider to be quality instruction to support or develop science literacy?

CHAPTER 2

Review of Literature

The purpose of this study was to explore sixth-, seventh-, and eighth-grade teachers' knowledge and beliefs about science literacy; specifically, how these teachers define science literacy and what they consider to be quality instruction in developing science literacy during instruction. In order to better understand existing research related to this issue, three bodies of literature are reviewed in this chapter. The review begins with a description of recent education reform efforts, with a focus on proposed goals in literacy and science instruction. Next, literacy, disciplinary literacy, and science literacy and the relationships among them are discussed. Finally, a brief review of the literature on teacher knowledge and beliefs about teaching, with an emphasis on science teacher, and their impact on instruction and educational reform is included.

Educational Reform and New National Standards

This section reviews the reasons for and salient events of the most current educational reform in the U.S. Included in the discussion are the stakeholders and their contributions, which have continued to propel the reform efforts forward. The section ends with an explanation of the development and publication of new national standards for English language arts (National Governors Association Center for Best Practices [NGA] & Council of Chief State School Officers [CCSSO], 2010), mathematics (NGA & CCSSO, 2010), and science (NGSS Lead States, 2013; National Research Council [NRC], 2012).

Preparing students to thrive in a climate of global competitiveness that is constantly changing is a national concern. In the 2014 White House Office of Science and Technology Policy, President Barack Obama asserted that students need specific skills and knowledge for a new workforce to meet the challenges of an information age, which include "problem solving, critical thinking, science, technology, engineering, and math" (p.1). The following year, $2.9 billion of government funding was appropriated for programs to prepare students with what the president described as 21st century skills (Science, Technology, Engineering, and Mathematics [STEM] Budget, 2014). The goal was to redesign educational programs to provide "students with challenging, relevant learning experiences that will help them gain the knowledge and skills they will need to succeed in today's economy" (p. 1).

The president's call was not unprecedented. It echoed previous appeals by other stakeholders, including business, education, and community leaders, who joined with government leaders during previous administrations through nonprofit organizations to push for changes in educational policy and practice (Achieve, 2015; Partnership for 21st Century Learning, 2015). One of these organizations, Partnership for 21st Century Learning (P21), was organized in 2002 as a coalition comprised of leaders in government (U.S. Department of Education), business (e.g., AOL Time Warner Foundation, Apple Computer, Inc., Dell Computer Corporation, Microsoft Corporation), and education (National Education Association). As an organization which remains operational today, its goal is to promote 21st century readiness in all students by providing them with the knowledge and skills required to "thrive in a world where change is constant and learning never stops" (P21, 2015, Our Vision and Mission Section, para. 1). The claim is what students are learning in school does not align with the knowledge and skills they will need to be successful in their future careers (P21, 2015). For example, a scientist must have an understanding of the content of science and an ability to communicate with others in the field of science (Norris & Phillips, 2003; P21, 2015). In other words, students need "expertise and literacies" in the different academic disciplines (e.g. science, mathematics, language arts, social studies) to be successful in a global economy (P21, 2015, Framework Definitions Section, p. 1).

Nearly a decade prior to the organization of P21, Achieve, another nonprofit organization formed by government and business leaders to align educational policy and practice to promote skills for the 21st century (2015), was assembled in response to an education summit organized by President George H.W. Bush in 1989. The summit was the first meeting of governors and the president concerning education since the Great Depression (New York State Archives, n.d.). In attendance were 49 governors from the National Governors Association (NGA) and various members of the White House administration. During the summit, performance benchmarks were discussed, which later informed the writing of six national education goals shared by President Bush in his 1990 State of the Union address (New York State Archives, n.d.). Much like those communicated by President Obama 24 years later, these goals centered on creating educational experiences that prepare students to be successful in a global economy. Six years following the address by President Bush, another summit hosted by IBM and NGA was held. At the meeting, Achieve was organized with the intent to accomplish the previously articulated goals for student achievement by "aligning key policies with the demands of the real world so that all students graduate from high school with the knowledge and skills…[for] college, careers, and life" (Achieve, 2015, About Us section, para. 2). The formation of P21 and Achieve represent efforts to promote 21st century skills in K-12 education.

The most recent fervor around adjusting educational policies and practices to prepare students for their future (Achieve, 2015; P21, 2015; White House Office of Science and Technology Policy, 2014) initiated the development of new education standards, as states collaborated with other stakeholders (NGA & CCSSO, 2010). In one case, representatives from the NGA and CCSSO including teachers, experts, school administrators, and parents from 49 states and territories were organized to develop new standards and benchmarks for literacy and mathematics. Aligned with the aims of the sponsoring stakeholders, the purpose of these standards was to set "clear expectations to ensure that all students have the skills and knowledge necessary to succeed in college, career, and life" (NGA & CCSSO, 2010, Frequently Asked Questions Section, para. 6). These standards include benchmarks for mathematics and English language arts, including specific attention to literacy in history/social studies, science, and technical subjects. The final draft, the *Common Core State Standards* (CCSS), was published in June, 2010.

Another set of discipline-specific standards soon followed the CCSS, which had "prompted interest in comparable documents for science" (NRC, 2012, p. 8). The *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) were initiated by a 2007 commission from the Carnegie Foundation and the Institute for Advanced Study, which was comprised of university professors from a number of well-respected institutions (e.g., Duke, Harvard, Stanford), business leaders (e.g. Wireless Generation, Carnegie Corporation), a high school teacher, presidents of universities, the president of the National Academy of Science, the Executive Director of the CCSSO, and other stakeholders. This committee concluded that "the nation's capacity to innovate for economic growth and the ability of American workers to thrive in the modern workforce depend on a broad foundation of math and science learning" (Carnegie Corporation of New York-Institute for Advanced Study Commission on Mathematics and Science Education Executive Summary, 2009, p. 1) and called for "a common set of standards in science to be developed" (NRC, 2012, p. ix). This led first to the development of a conceptual framework for the new standards, *A Framework for K-12 Science Education: Practices,* *Crosscutting Concepts, and Core Ideas* (Hereafter, The Framework; NRC, 2012), followed by the NGSS (NGSS Lead States, 2013). Both are based on "existing documents that outline the major ideas for K-12 science education" (NRC, 2012, p. 13), including *Science for All Americans: Project 2061* (American Association for the Advancement of Science [AAAS], 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and the *National Science Education Standards* (NRC, 1996).

Together, these new standards for literacy, mathematics, and science, define a 21st century knowledge and skill set for K-12 students that P21 previously described as "expertise and literacies," where expertise connotes knowledge and skills in a particular field (Oxford Learner's Dictionary, n.d.). The CCSS addresses two main fields or subject areas, mathematics and English language arts (ELA), while NGSS addresses science and engineering. It seems reasonable, even expected, that these standards would each specify knowledge and skills for students to master relative to their respective disciplines. Literacy or literacies that cut across the different standards are also explicitly included for the content areas in the ELA CCSS through the *Literacy in History/Social Studies, Science, and Technical Subjects* section (NGA & CCSSO, 2010). Additionally, the expectation set by the Committee on a Conceptual Framework for New K-12 Science Education Standards is that by the end of their K-12 education, *all* students

> …are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter the careers of their choice, including (but not limited to) careers in science, engineering, and technology. (NRC, 2012, p. 1)

This goal is different than just gaining knowledge and having skills related to doing science. It also suggests that the development of literacy in science education is imperative. Both the ELA CCSS and the NGSS appear to be emphasizing a new focus on discipline-specific literacy.

If students are to gain the 21st century skills of expertise and literacy in science education, teachers need to provide instruction for students that addresses both content knowledge and the ability to communicate in scientific ways. While science instruction has always focused on the development of content knowledge (Douglas, Klentschy, Worth, & Binder, 2006; Norris & Phillips, 2003; Pratt & Pratt, 2004), it is less clear whether it has traditionally emphasized support for students in developing their ability to communicate in discipline-specific ways about science and science ideas. How is literacy currently defined in science education? How would teachers attend to literacy in science education? The following sections of this literature review address these questions in light of the current dual emphases on preparing students with the skills and knowledge necessary "for their individual lives and for their roles as citizens in this technology-rich and scientifically complex world" as well as "providing the foundational knowledge for those who will become the scientists, engineers, technologists, and technicians of the future" (NRC, 2012, p. 10).

Literacy

In this section, meanings of literacy are discussed and a definition of how the term is used in this study is introduced. This is followed by a discussion of disciplinary literacy as literacy skills or practices specialized to a specific discipline (Moje, 2015; Shanahan & Shanahan, 2008). The section concludes with a brief review of the literature on science literacy related to this study.

While existing literature often uses the term as if its definition is universally understood, defining literacy is complex (Hodges, 1999; Keefe & Copeland, 2011; Ntiri, 2009). This is, in part, because literacy has been discussed as it relates to many different contexts: individuals, communities of people geographically and professionally, general citizenry, economics, and human rights (Irwin, 1991; Organization for Economic Co-operation and Development, 2010; United Nations Educational, Scientific, and Cultural Organization, 2006). Ntiri (2009) even suggests that to assign a single definition to literacy "can be quite limiting" (p. 98). On the other hand, in order to provide a context for this study, some parameters for how literacy is envisioned are needed.

Over time, the meaning of the word *literacy* has evolved. Historically, it was derived from *litteratus,* which is Latin for "a learned person" and represented someone who could read Latin (Hodges, 1999). In the 1500s, the definition shifted to imply "the ability to read and write in one's native language" (p. 19). This notion of literacy as the ability to read and write print text is still commonly in use today. More recently, the National Reading Panel's report (2000) did not specifically define literacy; rather, it listed five major areas of focus that comprise reading, if mastered. All of these areas converge around reading traditional written print and, by association, writing it (National Institute of Child Health and Human Development, 2000). Additionally, in its 2006 definition of literacy, the United Nations Educational, Scientific, and Cultural Organization stated that a literate person is someone "who can with understanding both read and write" (p. 18). Because literacy has been associated with learning to or having the ability to read and write, the term is commonly linked with the subject of language arts in education.

Although the idea that literacy is the ability to read and write has lasted through the centuries, broader definitions of literacy have emerged within the past three decades. For example, in the National Literacy Act of 1991 it was defined as "an individual's ability to read, write, and speak…to function on the job and in society, to achieve one's goals, and develop one's knowledge and potential" (Irwin, 1991, p. 7). A similar conception of literacy was recently proposed by the National Assessment of Adult Literacy (National Center for Education Statistics, 2009): "Using printed and written information to function in society, to achieve one's goals, and to develop one's knowledge and potential." Of note, both of these definitions include the ability to use reading and writing within a society for an individual's benefit (Keefe & Copeland, 2011).

Perhaps more comprehensive, still, is the idea that literacy is the ability to communicate. This definition subsumes all previous definitions by specifying that to be literate an individual can read, write, speak and listen to receive and express meaning within a given context (Hodge, 1999; ILA, 2015; Keefe & Copeland, 2011; Position Statement of the International Reading Association, 2012), where context is "a collection of cultural and communicative practices shared among members of particular groups" (The National Council of Teachers of English, 2013, 21st Century Literacies, para. 1). This conception of literacy echoes Gee's (2004) notion that it is "different patterns or correlations… [that] are associated with or map to particular social languages…associated with specific socially situated identities and activities" (p. 14). In other words, Gee proposes that literacy is a combination of the individual skills of speaking, listening, reading, and writing used appropriately for the purposes and tasks involved in being part of what Wenger (1998) refers to as a particular community of practice. Finally, the International Literacy Association broadens the definition of literacy by including critical thinking—the ability to reason, analyze, and interpret any form of communication (ILA, 2015, Position Statement of the International Reading Association, 2012).

Although literacy may be redefined many more times in the future to "reflect criteria for social, political, religious, and economic relevance and expectations" (Ntriri, 2009, p. 99), for the purposes of this study a synthesis of the definitions described above will be used. Here, literacy will include any form of communication that uses the ability to reason, analyze and interpret information to receive or express meaning within a specific community.

This communication uses many different modes, or ways to represent or express an idea (Lemke, 2004). Wyatt-Smith (2009) suggests, "meaning is made, interpreted, communicated and shared through many different representations…image, gesture, sound, music, speech, writing, gaze, movement *et cetera*—is a mode…to make meaning" (p. 72). Thus, if literacy involves comprehending and communicating meaning, where one is a receptive process and the other is an expressive process, through different modes, being literate must mean that an individual can negotiate more modes than just traditional print text. It must "encompass all modes of communication" (Keefe & Copeland, 2011, p. 96). Kliewer (2008) agrees that many modes are used to make meaning as part of being literate. These modes include visual, written, and other semiotic representations (Serafini, 2012) such as written words, images, diagrams, graphs, and others (Kress, 2010; Lemke, 1998, 2004). Again, in order to be literate, it is important to be able to receive and express meaning, using multiple modes of representation appropriate to the context (Airey & Linder, 2009; Coleman & Goldston, 2011; Huber, Dinham, & Chalk, 2015; Serafini, 2012; Wyatt-Smith & Kimber, 2009).

Disciplinary literacy. Recently, the literacy education community has begun to emphasize what is referred to as *disciplinary literacy*, in reference to literacy within different academic disciplines (Fang & Coatoam, 2013; Fang, 2014; Moje, 2007, 2008; C. Shanahan & T. Shanahan; 2014; T. Shanahan & C. Shanahan, 2008, 2012). This focus is evident in the inclusion of the *Literacy in History/Social Studies, Science, and Technical Subjects* section of the ELA CCSS (NGA & CCSSO, 2010). These standards stress that the skills students will need to be successful in college and careers involve more than just disciplinary knowledge. In addition, attention must be paid to facilitating student communication within different disciplines (NGA & CCSSO, 2010) because each discipline "has its own norms for how knowledge should be created, shared, and evaluated" (Shanahan & Shanahan, 2014, p. 636). According to Shanahan and Shanahan (2012), disciplinary literacy is "an emphasis on the knowledge and abilities possessed by those who create, communicate, and use knowledge within the disciplines" (p. 8). Thus, to be literate within a given discipline, students need a clear understanding of how individuals use communication to reason, analyze and evaluate content knowledge within the discipline to receive and express meaning (Fang & Coatoam, 2013; Fang, 2014; Moje, 2007, 2008, 2015; T. Shanahan & C. Shanahan, 2008; T. Shanahan & C. Shanahan, 2012; C. Shanahan & T Shanahan, 2014). Furthermore, these "literacy skills/strategies and disciplinary content are inextricably intertwined" (Fang & Coatoam, 2013, p. 628) such that students "must grow in both dimensions simultaneously. The ultimate goal of disciplinary literacy is that all students will develop deep content knowledge and literate habits of thinking in the context of academically rigorous learning in individual disciplines" (Moje, 2007, p. 10). In short, students need to understand the content (e.g., ideas, principles, skills), nature of a discipline (e.g., science), and the norms of its communication. This means that it is not enough for teachers to communicate in discipline-specific ways appropriately. Rather, instruction must be deliberately designed to help students acquire both the content knowledge and practices specific to each discipline, as well as the means of communication authentic to each discipline.

Disciplinary literacy differs from *content area literacy* (Shanahan & Shanahan, 2012). In content area literacy, the focus is on teaching general literacy skills and strategies (e.g., note taking, summarizing, comparing, organizing) that can be used across disciplines to receive and express meaning (Fang & Coatoam, 2013; Fang, 2014; Shanahan & Shanahan, 2012). In contrast, as noted previously, disciplinary literacy emphasizes the "unique tools" (p. 8), or the ways literacy is used within a discipline to gain and use knowledge along with knowing the content of the specific discipline (Moje, 2015). Existing research demonstrates that students need explicit disciplinary literacy instruction (Fang & Coatoam, 2013; Fang, 2014; Moje, 2007, 2008, 2015) because they generally do not comprehend these subtleties on their own (Stahl, Hynd, Britton, McNish, et al., 1996).

As discussed previously, being literate requires that individuals navigate multimodal texts. Siebert and Draper (2008) suggest that text has typically been referred to as "traditional print material in the form of words and sentences" (p. 236). However, each discipline uses different modes or representations when conveying ideas. Within a given discipline, "what allows these individuals to share and refine their disciplinary ways of knowing is the system of semiotic resources [modes] they develop to represent this disciplinary knowledge" (Airey & Linder, 2009, p. 2). These modes represent different types of text. As Fang (2014) suggests, "each discipline has its own culture…as well as ways of using…text and literacy" (p. 445). Thus, within each discipline receiving and expressing meaning is "dynamic, responsive, [and] contextualized" for that specific field (Hurber, Dinham, & Chalk, 2015, p. 45).

Science literacy. In the discipline of science, literacy is utilized in distinct ways. Scientists use literacy as a tool (Lemke, 2004) as they analyze, interpret, and evaluate information relevant to science (NRC, 2012; Yore, Bisanz, & Hand, 2010). Indeed, literacy is a critical component of how scientists complete their work (Hanrahan, 2009; NRC, 2012) in order to communicate and to think critically about the "physical phenomena in the natural world" (Pratt & Pratt, 2004, p. 397). This form of disciplinary literacy specific to the discipline of science is termed scientific or science literacy.

According to Norris and Phillips (2003), scientific literacy or science literacy "is understood in two related but distinct ways. In one sense, literacy means [the] ability to read and write. In the other sense, literacy means knowledgeability, learning, and education" (p. 224). The first, the *fundamental sense* of being scientifically literate, includes ways scientists communicate to receive or to express meaning. The *derived sense* includes the knowledge or content of science as well as an understanding of the nature of science, or how science works. For a person to be scientifically literate, both of these senses are inseparably entwined and work together. Thus, although the two senses might be discussed separately in theory, in reality they are not disparate parts. Scientists use both senses together fluently (Norris & Phillips, 2003).

Science literacy is also an important part of science education (Hand, Yore, Jagger & Prain, 2010; NRC, 2012; Pratt & Pratt, 2004; Wellington & Osborne, 2001; Yore, Bisanz & Hand, 2010). Science educators and researchers have argued that students must develop an understanding of science content as well as the ability to communicate in the language used within the discipline of science (Hanrahan, 2009; Norris and Phillips, 2003). Students in K-12 classrooms work toward developing science literacy (Hand et al., 2003) that mimics or parallels what scientists actually do as they use science literacy in their work. Moje (2015) describes this phenomenon as "apprentic[ing] and guid[ing] students" (p. 255) in a discipline by "providing all students with the opportunity to understand" how the discipline works (p. 259).

Although students in grades K-12 are not expected to attain science literacy to the same proficiency of scientists working in the field, they can work toward this level of proficiency as teachers help them to progressively develop science literacy (Moje, 2015; NRC, 2012). Therefore, supporting the development of science literacy involves helping students to simultaneously develop both literacy and content knowledge during instruction in science (Hand et al., 2003; Hand, Yore, Jagger & Prain, 2010; Norris & Phillips, 2003; Wellington & Osborne, 2001; Yore, Bisanz & Hand, 2010) to the appropriate degree for their developmental level (Moje, 2015; NRC, 2012).

In the classroom, science literacy is developed in many ways. Teachers help students to receive or express meaning from text along with critically thinking and reasoning about science (Anderson, 1999; Hand et al., 2003; Hand, Yore, Jagger & Prain, 2010; Moje, 2015). Teachers can also support this development by facilitating students' abilities to negotiate science text orally or in print, use argumentation, or create explanations based on evidence (NRC, 2012; Moje, 2015; Yore, Bisanz & Hand, 2010). Science literacy is additionally developed through discussions and debates between students (Moje, 2015; NRC, 2012; Wellington & Osborne, 2001); and while reading science textbooks and other science texts such as research journals, field notes, emails, newspapers, magazines, blogs, and websites (Hand et al., 2003; NRC, 2012; Moje, 2015; Yore, Bisanz, & Hand, 2010).

Developing this knowledge and skills is challenging because the "language of science" (Bisanz & Bisanz, 2004, p. 4) is constructed in language patterns that are more specialized and complex than the texts elementary students generally read (Fang & Schleppegrell, 2010). They are filled with jargon, use “passive voice and complex sentence structure,” and the ideas or concepts of science are represented in a variety of ways (NRC, 2012, p. 74). For example, the texts might include: words, symbols, graphs, figures, diagrams, tables, charts, mathematics, maps, images, and others (Airey & Linder, 2009; Coleman & Goldston, 2011; Deresz & Mattewson, 1982; Hand et al., 2003; Lemke, 1998; Norris & Phillips, 2003; NRC, 2012; Wellington & Osborne, 2001; Yore, Bisanz & Hand, 2010). These language patterns are often unfamiliar and often introduce comprehension challenges for students if teachers do not provide appropriate instructional support.

Critical components of developing science literacy are outlined in The Framework (NRC, 2012). It “describes a vision of what it means to be proficient in science” (NGSS, Three Dimensional Learning, p. 2), proposing three dimensions “that broadly outline the knowledge and practices of the science and engineering that all students should learn by the end of high school” (NRC, 2012, p. 29). These three dimensions include: Disciplinary Core Ideas, Crosscutting Concepts, and Scientific and Engineering Practices.

Disciplinary Core Ideas encompass the three major science disciplines (i.e., physical sciences; life sciences; earth and space science) along with engineering, technology, and applications of science. These core ideas (e.g., facts, concepts, generalizations, laws) establish the appropriate subject matter or content knowledge for instruction and are organized developmentally by grade bands: K-2, 3-5, 6-8, and 9-12.

Crosscutting Concepts are critical for understanding science and how scientists think. Specifically, they “have application across all domains of science…[that] need to be made explicit for students because they provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically-based view of the world" (NGSS Lead States, 2013, p. 4). According to The Framework (2012), they include:

1. *Patterns.* Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. *Cause and effect: Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. *Scale, proportion, and quantity.* In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. *Systems and system models.* Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. *Energy and matter: Flows, cycles, and conservation.* Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. *Structure and function.* The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. *Stability and change.* For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study. (NRC, 2012, p. 84).

Scientific and Engineering Practices "reflect those of professional scientists and engineers" (NRC, 2012, p. 42) as they make sense of the natural and designed world. This dimension "stresses the importance of developing students' knowledge of how science and engineering achieve their ends" and also aims to help strengthen students' competency with the different practices. They include: asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information (NRC, 2012). Those that seem to be particularly focused on developing students' ability to navigate the language patterns of science, both written and oral, are constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information.

Because being scientifically literate suggests a fluent ability in all three dimensions, as demonstrated by what scientists actually do in their field, students need access to instruction that promotes and cultivates these dimensions. Gradually, they acquire a developmentally appropriate degree of "such knowledge and abilities" (NRC, 2012, p. 2) as teachers help them to develop science literacy.

What is entailed in developing science literacy has been discussed earlier in the chapter. What is not well understood, however, is teachers' understandings of what science literacy is, what they believe is involved in developing science literacy during science and/or literacy instruction.

Teacher Knowledge and Beliefs

The final body of literature that provides context for this study addresses teacher knowledge and beliefs and how these cognitive constructs influence classroom practice. This is important to this study because the study explores teachers' knowledge and beliefs about the construct of science literacy. First, a brief review of the importance of studying these psychological constructs is included. Then, research that has focused specifically on science teacher knowledge and beliefs is reviewed as it pertains to this study. Finally, reasons for understanding why science teacher knowledge and beliefs are important to consider when implementing educational reform through new standards is explained.

Knowledge and beliefs. Because teachers are central to determining what and how students learn in schools (Jones & Leagon, 2014), a large body of research has been generated over the years about teachers' practices and what influences them, including their attitudes (e.g., Guskey, 1988; Reeves, 2006), personal characteristics (e.g., Galguera, 1998; Kesner, 2002), knowledge (Shulman, 1986; Verloop, van Driel & Meijer, 2001), and beliefs (Calderhead, 1996; Smith, 2005). This subsection of this chapter focuses on a portion of this body of research: teacher knowledge and beliefs.

Knowledge and beliefs have a complex relationship. As Bullough and Baughman (1997) assert, at times the terms are "used in confusing ways" by scholars, where "knowledge and belief appear synonymous, as though the way in which a belief is held…makes it true to the holder regardless of the presence or absence of supporting evidence" (p. 70). Additionally, they also argue that "if the boundaries separating belief and knowledge are removed completely, knowledge is reduced to belief, perhaps opinion, when most certainly not everything [we] believe can stand scrutiny or would be recognized as knowledge" (p. 71). It is helpful, then, to understand the nature of the relationship between knowledge and beliefs (Jones & Leagon, 2014; Pajares, 1992).

According to many scholars, knowledge has justifiable fact as a foundation (Pajares, 1992). It relies heavily on the denotation that facts are objective (Pajares, 1992) and carries an assumption of "certainty" (Thompson, 1992, p. 129) due to its reliance on confirming supporting evidence (Bullough & Baughman, 1997). This adherence to evidence makes knowledge bounded by reason and logic (Nespor, 1987). Because of this, knowledge is considered a cognitive, not an emotional structure (Jones & Leagon, 2014). Additionally, an individual's knowledge is constantly evolving as new information and experiences are incorporated into existing schema (Pajares, 1992). Therefore, knowledge constructs are fluid, not static.

For the individual who holds them, beliefs, in contrast to knowledge, tend to be more static and resistant to change because, to the individual who holds them, they often "represent eternal truths that remain unchanged …regardless of the situation" (Pajares, 1992, p. 312). However, there is some evidence that some beliefs do appear to be influenced by reasons or evidence and can be modified in light of new information or experiences (Smith, 2005). Beliefs are also unbounded by logic because they can defy reason and fact; indeed, they are a more "subjective way of knowing" and are intertwined with emotion (Smith, 2002, p. 46). Perhaps because of this, they have a "connotation of disputability" by others (Thompson, 1992, p. 129) and are "thought of as psychologically held understandings, premises, or propositions about the world that are *felt* to be true" (Richardson, 1996, p. 103, italics added). Importantly, however, beliefs seem to operate like knowledge in making decisions (Green, 1971) and can strongly predict behavior (Pajares, 1992).

As stated previously, even though knowledge and beliefs are not synonymous, they are closely associated (Bullough & Baughman, 1997; Pajares, 1992; Smith, 2002; van Driel, Berry, & Meirink, 2014). Jones and Leagon (2014) describe their relationship as a "continual, unavoidable interplay" (p. 830), which is "simultaneously integrated and independent" (p. 831). This complex relationship makes distinguishing between knowledge and beliefs confusing, difficult, and unclear (Abell, 2007; Bullough & Baughman, 1997; Clandinin & Connely, 1987; Pajares, 1992). It also makes it difficult to pinpoint where one ends and the other begins (Pajares, 1992), which, according to some researchers, is less important than understanding that both impact teaching and learning (Smith, 2002). Finally, because knowledge and beliefs are so entwined, with both affecting behavior, researchers "often choose to ignore the distinctions between them, treating them as a single construct" (Smith, 2002, p. 48). This is how they will be considered for the purpose of this study, which explores the impact of knowledge and beliefs on teacher thinking.

Science teacher knowledge and beliefs. In addition to knowledge and beliefs about teaching in general, research suggests that teachers possess knowledge and beliefs specifically related to science and science instruction. When looking specifically at science teacher knowledge, Abell (2007) developed a model modified from existing research models (Grossman, 1990; Magnusson, Karjcik, & Borko, 1999; Shulman, 1986). Her model interpreted science teacher knowledge as the interplay among science subject-matter knowledge (e.g., central ideas of science, content knowledge, reasoning and elaboration about science, understanding of the nature of science), pedagogical knowledge (e.g., instructional strategies, the learning process and learner development, classroom management) and knowledge of the teaching context (e.g., an understanding of the specific state, district, school, and student situations). In combination, she asserted, these aspects interrelate to create *pedagogical content knowledge*, which is "the transformation of subject-matter knowledge into forms accessible to the students being taught" (Geddis, 1993, p. 675). Teacher knowledge also includes general knowledge, which is all the knowledge a teacher has about students, teaching and learning, curriculum, and so forth, at a certain time that is a foundation for his or her actions (Carter, 1990). Science teacher knowledge, therefore, includes components of general knowledge, science content knowledge, and pedagogical content knowledge.

Together, these knowledge bases impact teacher thinking and practice by affecting the selection of instructional strategies, teaching practices, "orientation[s]…or general way of viewing or conceptualizing science teaching" (Grossman, 1990, p. 97), science curriculum, and forms of student assessment (Abell, 2007). Thus, science teacher knowledge ultimately impacts what happens during science instruction (Abell, 2007).

While understanding how science teacher knowledge impacts teacher practice is important, understanding science teacher beliefs is no less critical. For decades, psychological and educational researchers have shown that understanding teacher beliefs is essential for understanding classroom practice (Richardson, 1996). Jones and Leagon (2014) have summarized this research, suggesting that science teachers' beliefs about (a) how students learn science, (b) what constitutes knowing in science, (c) the nature of science, (d) the appropriate design of instruction and instructional strategies for science, (e) the amount of time spent on science instruction, and (f) the students currently in the classroom together impact how science teachers' think and design their instruction. As a consequence, science teachers' beliefs significantly influence what happens in the classroom in distinct ways specific to the discipline of science.

Implications for implementing new science standards. According to Paul Dehart Hurd, "Teachers teach what they believe in" (in Bybee, 1993, p. iv). Therefore, with educational reforms changing the standards of what students are to learn in science, understanding what science teachers know and believe becomes critical to understanding teacher practice. Teacher knowledge and beliefs are, in fact, an essential link between the implementation of curriculum reforms, education standards, and what happens in the classroom (Bybee, 1993) because "any effective transformation of science teaching rests with the teacher" (Paul Dehart Hurd in Bybee, 1993, p. iv). In essence, the teacher who teaches science is ultimately the one who either "enacts or ignores reform initiatives" (Smith, 2002, p. 32).

Recognizing that teachers "play a central role in mediating education change…and reform implementation" (Smith, 2002, p. 34) is imperative for understanding teachers' practice and their inclination to resist or to implement a change in their instruction. Having an understanding of science teacher knowledge and beliefs becomes a foundation from which educational change can build because "successful, sustained reform is largely dependent on…teachers' ability to develop new knowledge, skills, and beliefs about science and what it means to teach and learn science—to fundamentally change the way [they] think about science education" (p. 4). This, again, underscores that understanding teachers' current knowledge and beliefs is essential (Pajares, 1992; van Driel, Berry, & Meirink, 2014) because how teachers think about standards "profoundly affects the way teachers teach" (Smith, 2002, p. 33). In other words, what teachers know and believe about new and existing standards is made visible in the classroom through their practice. More specifically, teacher knowledge and beliefs affect practice (Jones & Leagon, 2014) and understanding what happens during instruction includes conceptualizing teacher knowledge and beliefs (Jones & Leagon, 2014). Thus, exploring what teachers at different grade levels know and believe in regard to the new science and literacy standards is critical to efforts to change their practice.

Research Purpose

While researchers acknowledge that teachers' knowledge and beliefs impact the uptake of reform (Smith, 2002), what is not known is how they conceptualize science literacy and how to develop it during instruction. The goal of this study is to gain insight into how teachers in grades 6-8 define science literacy, or disciplinary literacy in science, and how they believe it should best be developed and supported during instruction.

CHAPTER 3

Method

The purpose of this study was to explore sixth-, seventh-, and eighth-grade teachers' knowledge and beliefs about science literacy. Specifically, how sixth-, seventh-, and eighth-grade science teachers describe science literacy and what they consider to be quality instruction in developing science literacy during science instruction.

With this purpose in mind, the following research questions guided the study:

1. How do sixth-, seventh-, and eighth-grade teachers describe science literacy or disciplinary literacy in science?
2. How do sixth-, seventh-, and eighth-grade teachers differ in their knowledge and beliefs about science literacy?
3. What do these teachers consider to be quality instruction to support or develop science literacy?

This chapter describes the research design, participants, context of the study, data sources, data collection, and data analysis that were used to answer these questions. Also included are descriptions of the researcher perspective and possible limitations of the study.

Research Design

According to Marshall and Rossman (2011), there are three possible purposes for qualitative research: "to explore, explain, or describe a phenomenon" (p. 68). In order to explore and describe trends in teachers' (a) knowledge and beliefs about the literacies involved in teaching and learning science, and (b) role in helping students to develop science literacy, a descriptive research design (Fraenkel & Wallen, 1993) using survey research methodology (Gall, Gall, & Borg, 2003) was employed.

Survey research can be conducted by administering interviews or questionnaires. While interviews enable the researcher to clarify questions and probe deeply into participants' beliefs and knowledge, questionnaires typically facilitate data collection over a wide geographic area more efficiently in terms of cost and time (Gall et al., 2003). For this study, a questionnaire, a self-report measure that enables the researcher to make inferences about "how individuals differ on various aspects of self," asking them "to reveal whether they have the traits, thoughts, or feelings mentioned in the items" (p. 189), was used. Survey research can be used to learn about a population of individuals by asking questions of either the entire population or a representative sample of the population in order to reveal current trends in that population (Creswell, 2012; Gall et al., 2003). By collecting data at one point in time to create a snapshot of current realities, this study used a cross-sectional survey design (Creswell, 2009, 2012).

Participants

Participants in this study were teachers in Grades 6-8 assigned to teach science during part or all of their instructional time and were selected from five school districts located in the same state in the western region of the United States. (For the purpose of this study, and in order to maintain confidentiality, school districts are designated by the letters A-F.) These participants separated into two distinctive population, elementary and secondary, based on their teaching context. One group, elementary, considered to be "generalists" (e.g., Abell, 1990; Anderson & Clark, 2012; Li, 2008), were sixth-grade teachers in the state who are generally prepared and assigned to teach all academic subjects (e.g., English language arts, mathematics, science, social studies) in an elementary school setting. In contrast the second group, seventh- and eighth-grade teachers, are prepared to teach a specific academic discipline (e.g., science), and are considered to be "content specialists" (e.g., Ness, 2009; Shanahan & Shanahan, 2008). They are assigned to teach this subject for most or all of the school day in a middle school or junior high school setting. These two populations of teachers were selected as participants in order to compare how teaching context may influence teachers' knowledge and beliefs about teaching and learning science literacy.

The target population consisted of 542 sixth-grade teachers and 190 seventh- and eighth-grade teachers. A total of 165 sixth-grade teachers (30.4%) and 70 seventh- and eighth-grade teachers (36.8%) completed all sections of the questionnaire, resulting in 235 (32.1%) useable surveys.

Context of the Study

Four of the five districts (A-D) situated sixth-grade classrooms in a K-6 elementary school setting. In this organizational model, the classroom teacher was assigned to teach all core subjects, including mathematics, language arts, science, and social studies. In District E, although Grades 5-6 were separated from Grades K-4 and placed together in an intermediate school, the sixth-grade teachers in these schools taught all core subjects in the same way the elementary teachers did in the other participating districts. Therefore, for the purposes of this study, sixth grade in District E was considered as an *elementary* setting. Grades 7-8 in all districts were located in either a middle school or a junior high school, where science teachers were assigned to teach only science. In order to reduce confusion, both of these school labels are referred to as *secondary* (see Table 1).

All five school districts were members of a long-standing university-public school partnership, making selection of participants, in part, one of convenience (Lund Research, 2012). More importantly, however, students and teachers in these districts represented nearly one-third of the sixth-, seventh-, and eighth-grade student population and one-fourth of the sixth-grade

Table 1

Number of Elementary Schools, Middle Schools, and Teacher Numbers by School District

	Number of Schools		Number of Teachers	
District	Elementary Schools	Secondary Schools	6^{th} Grade	$7^{th}/8^{th}$ Grade[a]
A	57	12	208	80
B	13	2	38	11
C	27	7	141	36
D	34	10	140	57
E	5	2	15	6
Total	136	33	542	190

Note. Data collected from district websites.
[a]These educators teach only science courses.

teachers and seventh- and eighth-grade science teachers in the state (Utah State Office of Education, 2009). Having a sample this large (see Table 1) enabled the researcher to represent the knowledge and beliefs of the population of participants more accurately (Creswell, 2012).

Participating school districts included a range of urban, suburban (urban clusters), and rural areas, which provided a wide variation of teaching contexts, making the target population more representative of the population of teachers across the state. According to the United States Census Bureau (2015), urban and rural geographic classifications depend on specified population criteria. Thus, a geographic area is identified as *urbanized* if the population is 50,000 or higher and is comprised of "a densely settled core of census tracts and/or census blocks…along with adjacent territory containing non-residential urban land uses" (Geography section, para. 2). An *urban cluster*, which represents a geographic area with populations from 2,500 to 49,999. *Rural* areas are those that include "all population, housing, and territory not included within an urban area" (para. 2).

The demographics of each of the school district communities can be found in Table 2. Of note, the race/ethnicity of the total population in all communities and school districts in the study was predominately White, with Hispanic/Latino representing the majority of the remaining population. Because parents may select all race/ethnicity categories that apply to their children when designating this demographic for school records, the total percentage in the table may add up to more than 100%. Also notable is that socioeconomic status (SES) of students was designated by participation in the free and reduced lunch programs provided by the schools, and differs by district.

The following paragraphs offer a brief description of each of the school districts from which the participating teachers were drawn, highlighting relationships among them.

District A. District A consisted of 11 geographic areas in close proximity. Two were classified as urbanized, seven were considered urban clusters, and two were rural. The total

Table 2

Participating School District Demographics

District	A	B	C	D	E
Total Student Population	73,472	16,600	31,393	51,806	5,959
Hispanic/Latino	10.0%	24.7%	10.4%	13.5%	17.2%
American Indian	1.7%	1.5%	0.8%	4.8%	0.3%
Asian	2.2%	2.9%	0.9%	3.2%	0.9%
African American/Black	1.5%	1.6%	1.0%	2.5%	0.7%
Pacific Islander	2.1%	3.9%	1.4%	2.6%	0.4%
White	95.9%	92.5%	97.6%	91.5%	98.5%
Free/Reduced Lunch	24.0%	39.8%	33.7%	42.1%	28.4%
Native Language Spanish	3.8%	19.0%	6.8%	3.3%	15.0%

Note. Data collected from the October 1 Report 2014: UTREx Clearinghouse Report and from individual district websites.

population of these communities was approximately 305,000. This was the largest of the five districts by student population and had the lowest free and reduced lunch rate. District A also had the lowest Hispanic/Latino student population (10%).

District B. This school district was located in one urbanized geographic area with a population of approximately 116,000. The district included the highest percentage of Hispanic/Latino students (24.7%) and native Spanish speakers (19%) in the study.

District C. District C was comprised of seven urban clusters and one rural area. Although the total population of 116,000 was nearly identical to that of District B, the student population was double that of District B.

District D. Situated within one urbanized geographic area surrounded by three large urban clusters, the total population of the communities was 201,000, with 110,000 people located in the urbanized area. Not surprisingly, the ethnic composite for the urbanized area differed from the urban clusters, where the White population was more concentrated. District D was the second largest participating school district by student population (51,806) and had the largest free and reduced lunch rate (42.1%).

District E. This school district consisted of one urban cluster with surrounding rural area. The population was approximately 27,000. Of the five participating districts, this was the smallest district by student population (5,959), but had the second highest percentage of Hispanic/Latino ethnicity (17.2%) and native Spanish speakers (15%).

Data Source

The data source in this study was a questionnaire designed to investigate teacher knowledge and beliefs related to science literacy from a large sample of teachers (See Appendix A). Questionnaires have the advantages of (a) being economical; (b) allowing for quick turnaround; (c) enabling participants to respond anonymously, where appropriate, thereby lowering bias in responses; and (d) permitting efficiency in administration over a large geographical area (Babbie, 1990; Creswell, 2009, 2012; Fowler, 2002; Gall et al., 2003). Because the research questions in this study required responses that enabled the researcher to infer teacher knowledge and beliefs from a large population and a fairly large geographical area, utilizing a questionnaire for the survey was appropriate. Marshall and Rossman (2011) also suggest that surveying a large population is commonplace in contemporary research due to third party survey sites such as *qualtrics.com.*

Survey questions can be either *closed form* or *open form* (Gall et al., 2003). Closed form questions allow participants to select only from a list of predetermined responses. Open form questions, on the other hand, encourage the participant to respond freely, without the restraint of preselected answers. They also invite participants to include more detail and personalization in their responses (Creswell, 2012; Gall et al., 2003). To capture these advantages, both open form and closed form questions were utilized in the two-part questionnaire developed for this study. The first part was comprised of open and closed form questions; the second part included demographic questions.

Part one of the survey questionnaire. Prior to administering the initial survey to all participating teachers, the open form survey questions were piloted with a group of ten teachers. This group was comprised of sixth-grade elementary teachers and seventh- and eighth-grade science teachers selected from the five partnership districts, who were asked to respond to the prompts. Feedback regarding organization, clarity, and wording was gleaned during this process to ensure the items served as appropriate prompts that addressed the research questions. The instrument was then revised by incorporating teacher comments (Creswell, 2009; Gall et al., 2003).

Each item was crafted to address specific research questions. The following subsections delineate which survey questions address each research question and are organized per research question.

Research question #1. The first two survey questions asked teachers to describe what they think of as literacy and what they consider to be text (see Appendix A). These questions probed teachers' understanding of what constitutes general literacy (Irwin, 1991; Keefe & Copeland, 2011).

The third survey question asked teachers to identify or describe what they consider to be texts used in communicating about science or within the discipline of science. Because each academic discipline uses a variety of texts to communicate ideas and practices among members of the community of practice (Wenger, 1998) or within the Discourse (Gee, 2002), responses to this question garnered participating teachers' knowledge and beliefs about how people communicate or use literacy specifically within the discipline of science. For example, texts used in science discourse include science textbooks, research journals, field notes, emails, newspapers, magazines, blogs, and websites (Hand et al., 2003; NRC, 2012; Moje, 2015; Yore, Bisanz, & Hand, 2010).

The fourth survey question asked teachers to describe what science literacy means to them. This directly probed teachers' knowledge and beliefs about what constitutes science literacy. All of these four questions help to create understanding about teacher thinking in regard to describing general literacy and ultimately science or disciplinary literacy, which is the focus of the first research question.

Research question #3. To understand what types of learning activities participating teachers believe are most appropriate in developing science literacy in both the fundamental as well as the derived senses (see Norris & Phillips, 2003), instances, or IAIs, were used instead of asking the participants direct questions as a means of accessing participants' beliefs and knowledge more accurately (Southerland, Smith, & Cummins, 2000). This is because individuals may be unable to clearly describe their perspectives or may provide answers that do not necessarily reflect their true beliefs, instead reflecting what they may think is a "correct" response (see Munby, 1982). Nott and Wellington (1998) refer to these types of questions as "critical incidences," where "part of the incidents' criticality is that they evoke responses from the teacher which provide an insight into the teachers' view of science as well as matters to do with teaching and learning" (p. 582). In this way, teachers share more accurately their beliefs about science and science teaching.

For the purposes of this study, six instances or instructional scenarios were included as survey items 5-10. These scenarios were developed based on two articles found in *Science and Children* (Blank, Snir, & Lundsgaard, 2015; Vardell & Wong, 2014) and personal interaction with classroom teachers. They were designed to illustrate different ways literacy is commonly taught or used in classroom science instruction. Teachers were first asked to rate each scenario from 1-6 in terms of quality or "best practices in teaching science literacy" (with six demonstrating the highest level of best practices). They were then asked to provide a brief explanation for their rating.

Research question #2. All survey questions provided information to answer research question #2: How do sixth-, seventh-, and eighth-grade teachers differ in their knowledge and beliefs about teaching and learning science literacy? Because all participating teachers were asked to complete the survey, during the analysis (described below) information gleaned from their responses was grouped by sixth or seventh and eighth grade to compare differences between teacher knowledge and beliefs about teaching and learning science literacy according to elementary or secondary categorizations as explained previously.

Part two of the survey questionnaire. The second part of the survey questionnaire contained demographic questions. These included questions regarding (a) grade(s) currently being taught, (b) subject(s) currently being taught, (c) years of teaching experience, (d) years of teaching experience in science, (e) gender, (f) preparation: elementary or secondary teacher education program, and (g) endorsements or graduate degrees obtained (Gall et al., 2003).

Data Collection

The questionnaire was distributed via public school district email to the entire population of *elementary* teachers and *secondary* science teachers (Grades 6-8) in the five participating school districts. As suggested by Creswell (2009), the email contained a message introducing the researchers, explaining the purpose of the study, inviting teachers to participate, and providing a link to a third-party survey site, *qualtrics.com* (see Appendix C). More specifically, the email included an introductory page that provided a description of the purpose of the study, expectations of the participants, associated risks and benefits, contact information for the researcher, members of her thesis committee, and the University Institutional Review Board, and an explanation of implied consent. Upon opening the provided link, the survey questions became available for participants. Completion and submission of the survey signified participant consent.

Prior to distributing the questionnaire, permission for teachers to participate in this research was obtained from each school district. The email described above was then sent to potential participants. Identical follow-up emails were sent out at two- and four-week intervals after the initial email to encourage response. These reminders included a note of thanks for those who had already chosen to respond (see Appendix D).

Respondents were assigned a number by which they were identified. Only the researcher and her advisor knew the participant identities; all raw data was stored on a password-protected computer in a locked office.

Researcher Stance

Every researcher has a perspective or lens through which the research data are perceived. This perspective emerges from the everyday experiences and events that happen as a person progresses through life. No two people have exactly the same history, so no two people will see life in precisely the same way. As a researcher, it is important to be open about one's identity and perspectives so that the reader has access to the lens through which the qualitative data was analyzed (Marshall & Rossman, 2011). To facilitate reader understanding of the researcher lens, I disclose the perspectives that inform my identity in regard to science literacy, the focus of this study.

My identity hinges around two distinct perspectives: student and educator. During undergraduate studies, I discovered a desire to learn about many subjects. Elementary education seemed like the appropriate avenue to explore because the elementary education program included how to teach a variety of disciplines. After graduation and while teaching elementary students, I continued to be a student by completing an English as a Second Language Endorsement. The impetus behind gaining this knowledge was to help students with limited English proficiency become literate. A desire to help all students attain a higher literacy level followed as I then completed both Reading and Advanced Reading Endorsements.

At a meeting where I was invited to participate in a state educator team to align the state ELA standards with the CCSS (NGA & CCSSO, 2010) for sixth-grade ELA, a major disagreement ensued among the attending secondary ELA teachers. The discord was focused on who was responsible for literacy instruction: the ELA teacher or the content area, discipline-specific teacher. To help answer this question on a personal level, I enrolled in a Master of Arts in Teacher Education graduate studies program with a specialty in Integrative STEM Education to gain more knowledge about instruction in disciplines other than ELA. I also completed a STEM endorsement. This research project was a result of my quest to understand current teacher knowledge and beliefs in regard to literacy and science literacy in science instruction.

From an educator perspective, I taught science, mathematics, ELA, and social studies in either a fifth- or a sixth-grade classroom for nine years. My original elementary student teaching assignment was completed in a school that contained a higher rate of ethnic diversity than many of the schools in the district. Later after working in four different schools, I experienced a range of socioeconomic, school size, and cultural differences. In an effort to support literacy in all students, I was prompted to design and present professional development for district teachers and later teachers throughout the state. A small amount of this professional development was in science and mathematics. The majority focused on ELA and ESL.

Currently, I am involved in education as the K-6 science specialist for a school district. Introducing sixth-grade teachers to the new Utah Science with Engineering Education (SEEd) Standards (Utah State Board of Education, 2015) and three-dimensional science instruction has been my assignment for the past two years. Also, working on state teams to write items for the end of year ELA and Science assessments has provided me with insights for supporting teachers within the district in which I am employed. In addition to working with teachers in my district, I continue to write and facilitate professional development for the State Board of Education in ELA, engineering design, and ESL. This professional development is distributed through two mediums: personal contact and online university courses. Through these experiences, my desire is to provide forums for all educators to collaboratively explore how students negotiate meaning in the disciplines of science and ELA.

Data Analysis

The questionnaire yielded a large amount of data. However, this information alone does not inform understanding. The data had to be analyzed to draw conclusions about it (Creswell, 2012). In this study, the questionnaire included both closed form and open form questions.

The process of analyzing responses to open form questions is complex. In order to create meaning and develop an understanding of a phenomenon from the compiled information obtained through open form questions (Basit, 2003; McCracken, 1988), a system is used to bring "order, structure, and interpretation to a mass of collected data" (Marshall & Rossman, 2011, p. 207). Coding is one way to accomplish this task (Basit, 2003; Creswell, 2012; Marshall & Rossman, 2011; McCracken, 1988). It is a systematic and thoughtful way to assign units of meaning to compiled research data and leads to synthesis or analysis of those meaning units into broader themes that describe the phenomenon (Basit, 2003; Creswell, 2012; Marshall & Rossman, 2011). Even through there is not one preferred way to code (Creswell, 2012), experts suggest that a study consider ways to organize, code, and interpret the data as part of the data analysis phase (Creswell, 2012; Marshall & Rossman, 2011).

Organizing the data. An immersion style of coding was used to organize questionnaire data after it was returned (a) across all responses for each survey question and (b) within elementary and secondary teacher designation. In immersion style coding, the researcher reads each piece of data and looks for codes and themes within the context of the text (Marshall & Rossman, 2011; Miles & Huberman, 1994). This coding provides an intimate relationship with the data as codes emerge during piece-by-piece hand analysis (Creswell, 2012) after the participant responses are collected.

Coding the data. To code the data, general steps described by Tesch (1990) and Creswell (2012) were utilized. Their suggested system for coding was specifically implemented in the following way:

1. Twenty responses for survey question #1 were randomly selected by the researcher.
2. The researcher, her thesis chair, and one committee member individually read each of the twenty responses to look for emergent codes that arose within each text and themes that emerged between different participant responses.
3. The team then met together and compared codes for each response and themes between responses coming to consensus on any differences.
4. Code words and themes were added to a Codebook (see Appendix E).
5. A second sample of 20 responses were randomly selected from survey question #1.
6. Again, the team individually coded the new set of data.
7. Meeting a second time, the team compared their coding for each response and any themes they discovered with the intention to determine consistency (Marshall & Rossman, 2011) or interrater reliability. For question number one, the team had an 88% consensus rate.
8. The remaining responses for survey question #1 were coded independently by the researcher.
9. This process was repeated for survey questions 2, 3, and 4. The interrater reliability was 81%, 88%, and 72%, respectively, with an overall consensus rate of 82.25%.

10. The researcher then coded teachers' responses for each of the six instructional scenarios. After completing this process, the team met together to discuss the codes and themes that emerged.
11. The closed form teacher ratings (1-6) for the scenarios were then compiled into three groups, 1-2, 3-4, and 5-6, according to teachers' ratings using a counting process (Patton, 2002)
12. After the count of ratings was completed, the open form explanation for each teacher's rating was assigned to the corresponding count group.
13. After all coding of the four survey questions and six scenarios was complete and the explanations for teachers' ratings were assigned to corresponding rating groups, the researcher met with her chair to discuss compressing the codes into even broader themes (Marshall & Rossman, 2011). Creswell (2012) explained that after the list of codes is compiled, broader themes that subsume codes can be generated where applicable. These themes are expected, unexpected, hard to pin down, or categories with underlying subsets. The final codebook is located in Appendix E.

Interpreting the data. At this point in the analysis, the researcher looked for ways to integrate the themes or codes into an "interpretation of what she has learned" (Marshall & Rossman, 2011, p. 219), across grade levels and within elementary and secondary teacher designations, making meaning and creating cohesion among the codes. According to Patton (2002), "Interpretation means attaching significance to what was found, making sense of the findings, offering explanations, drawing conclusions, extrapolating lessons, and making inferences, considering meanings, and otherwise imposing order" (p. 480). In order to create meaning, the researcher, chair, and committee member decided to group participants' in two different ways: low, medium, or high based on how well they recognized instruction authentic to science, and elementary or secondary based on teaching context.

Designation of low, medium, or high. To understand the low, medium, or high designations, an explanation of (a) the criteria used to construct the teaching scenarios, and (b) how teacher responses to the scenarios were grouped are explained in the following sections.

Criteria used to construct scenarios. The six teaching scenarios in the survey were designed to vary according to their level of use of best practices, where best practice was determined by the authenticity of the use of science practices described in the scenario. The criteria for determining authenticity was based on descriptions of authentic scientific practices found in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* [The Framework] (NRC, 2012) and the *College and Career Readiness Anchor Standards for Reading and Writing* found in the *ELA CCSS* (NGA & CCSSO, 2010; see also Appendix B). In The Framework authenticity of instruction designed to teach science literacy is determined by how students are asked to use scientific practices as they learn science. The term "practices" is the term used "instead of a term such as 'skills', to stress that engaging in scientific inquiry requires coordination both of knowledge and skill simultaneously… [These] practices should reflect those of professional scientists" (NRC, 2012, p. 41).

To develop practices similar to scientists and to help them to better understand how science works, student tasks during science instruction should, therefore, include learning how to read, write, speak, and listen to science text in order to learn science concepts and to communicate science information in discipline specific ways. This is referred to as scientific or science literacy, which is "essential to developing an understanding of science" (NRC, 2012, p. 75). Indeed, "reading, interpreting, and producing text are fundamental practices of science in particular, and they constitute at least half of engineers' and scientists' total working time" (p. 74). Additionally, the *Anchor Standards for Reading and Writing* found in the *ELA CCSS* (NGA & CCSSO, 2010) also "recognize[es] that reading and writing skills are essential to science…Science simply cannot advance if scientists are unable to communicate their findings clearly and persuasively" (NRC, 2012). According to these standards, science literacy "requires an appreciation of the norms and conventions of [the] discipline…students need to be able to gain knowledge from challenging texts that often make extensive use of elaborate diagrams and data to convey information and illustrate concepts" (NGA & CCSSO, 2010, p. 61).

Using criteria from these documents as a guide to construct the scenarios for the survey (Survey Questions 5-10), three gradients of science literacy or literacy authentic to the discipline of science were employed: authentic, partially authentic, and not authentic. (For a detailed description of the way these criteria were used in developing the scenarios utilized in this study, please see Appendix B). For example, in a scenario that was constructed to depict the use of *Authentic* science literacy during instruction, students were presented with a question asking how individual organelles in a Euglena (protist) contribute to the function of the whole organism. They observed a video of Euglena under an electron microscope, used a computer application to draw a model of a Euglena, labeled the organelles, and noted the organelles' functions within the whole organism. In pairs, students were then asked to compare their models and note discrepancies. Finally, the pairs compared their models to a model of a Euglena found in a science textbook, revised organelle functions where appropriate, and wrote an explanation of how the individual organelles contributed to the function of the whole organism (survey question #6).

In this scenario, in addition to learning science concepts (developing science subject matter knowledge), students answered a question, developed and used a model, constructed explanations, and obtained, evaluated, and communicated information, which are all communicative practices authentic to science (NRC, 2012). Additionally, students were "reading closely to determine what the text says explicitly and…making logical inferences from it" (NGA & CCSSO, 2010, p. 35). They were also expected to write clear explanations appropriate for the audience, investigate a research question, and collect information from relevant sources, which are expectations of the *Writing Anchor Standards* in the ELA CCSS (NGA & CCSSO, 2010). In short, the students were using communicative practices authentic to science during the learning process, which would support their ability to develop science literacy.

In contrast, an example of a teaching scenario (survey question #5) that is *Not authentic* depicted students reading a section of a textbook that described how force is used to hold celestial objects in orbit around larger objects of greater mass in the solar system. Using that information, students were asked to create a Haiku or Cinquain poem that describes the role of gravity in the orbits of the Earth and Moon. Students were then instructed to illustrate their poems using watercolors in the Impressionist style of Monet and Renoir.

Although reading from a textbook would be considered an authentic science practice, the poem students are asked to construct does not communicate information in the way scientists formally write an explanation (e.g., journals, books, articles, websites). Nor is poetry an informal form of communication used by scientists (e.g., email, discussion, blogs, notes; NRC, 2012). Additionally, the *Writing Anchor Standards* in the *ELA CCSS* call for students to "produce clear and coherent writing in which the development, organization, and style are appropriate to the task, purpose, and audience" (NGA & CCSSO, 2010, p. 41). Therefore, writing an illustrated poem is not an authentic task completed by scientists to communicate their findings.

Finally, a *Partially authentic* depiction of teaching science literacy is demonstrated in the following scenario (survey question #9): Students observed microorganisms found in pond water under a microscope, drew examples of the microorganisms, read about them in a textbook, and recorded information in a concept web graphic organizer. They then wrote a summary of the text based on information in their concept web.

According to the The Framework, in this scenario the students were communicating information by drawing and writing about their observations, which is a practice authentic to science discourse. However, the purpose for the observation of microorganisms is unclear or generic because students lack a focus question or investigation question to help them develop a model or explanation of the phenomenon. Additionally, students were reading text and writing text to accurately describe information according to the *Reading and Writing Anchor Standards*; however, they were using the standards in a general, content area literacy way that lacks a more specific focus for developing science literacy. Therefore, this scenario only partially emphasizes practices authentic to developing science literacy.

Teacher responses to scenarios. In developing the questionnaire, each scenario was designed to be Authentic, Partially authentic, or Not authentic according to the criteria described in Appendix B, and assigned a rating of 1-2 (Not authentic), 3-4 (Partially authentic), or 5-6 (Authentic). When completing the survey, participating teachers were asked to rate each of these scenarios based on the authenticity of science literacy utilized in the scenario. They were also asked to explain their reasoning for the assigned rating. These explanations provided some evidence of teachers' perceptions of practices that would best help children develop science literacy.

During analysis, teacher ratings were compared to the designed instrument ratings. A teacher rating that matched the designed rating was counted as a match. The total number of matches between the participant rating and the designed scenario rating were compiled. If a teacher rating and scenario rating matched 0-1 out of six possible times, the teacher was placed into a group designated *low* for low teacher understanding of science literacy instruction. Similarly, if the participant and survey ratings matched 2-3 times, the overall designation for the teacher was *medium* meaning medium teacher understanding. Finally, if the teacher rating matched the survey rating 4-6 of the times, the teacher was placed into a group designated *high* for high teacher understanding of authentic science literacy instruction.

Counting as an interpretation tool. To create meaning, the number of times each code was included in participants' responses was counted. This process of counting allowed the researcher to ascertain trends in teacher responses by extrapolating highly utilized codes and themes (Patton, 2002) among each participant designation and across all designations.

Elementary or secondary. The second way teacher responses were grouped was by teaching context. These designations were described previously with *elementary* denoting sixth-grade teachers who typically teach all core subjects and *secondary* for seventh- and eighth-grade teachers who typically teach only science.

Limitations

General limitations are associated with self-report measures, including threats to validity due to participants' tendency to misconstrue the meaning of questions (Gall et al., 2003), resulting in responses that do not accurately reflect participant perceptions. To help reduce these errors, open form questions were used in the questionnaire to address participants' knowledge and beliefs by asking them to provide specific examples adding to the richness and range of possible responses (Marshall & Rossman, 2011).

Another potential limitation was sampling error (Creswell, 2012). To minimize this issue, all the sixth-, seventh-, and eighth-grade teachers included in the research sample were asked to respond to the questionnaire. According to Creswell (2012), selecting the largest sample size available helps to assure that participant responses represent the population trends.

Establishing a valid measurement tool was a third issue associated with survey research (Creswell, 2012). In attitudinal measurement tools, researchers often create the instrument for the purpose of the study, as was done in this study. Thus, the instrument may lead to false inferences because the questions are misleading, unclear, or participants do not provide direct evidence of their specific knowledge and beliefs (Creswell, 2012). To lessen these validity issues, a pilot study was completed with ten sixth-, seventh-, and eighth-grade teachers to check for question clarity, ease in understanding how to respond, and intended question purpose. Feedback was gathered from this pilot study and the instrument was revised to increase the level of reliability and validity (Creswell, 2012; Gall et al., 2003).

A fourth possible limitation to this study was nonresponse error. To increase the response rate, "rigorous administrative procedures" (Creswell, 2012, p. 282) were applied. These procedures included a cover letter with the questionnaire that contained a clearly stated purpose and importance for participation, assurances of anonymity, return date, and a reminder email sent out two weeks and four weeks after the initial survey request. Additionally, a small incentive was included to increase participation. Any participant who submitted a completed survey could chose to enter a random drawing for five $100 VISA gift cards.

Lastly, the researcher may not understand all of the implications and meanings within participant responses (Marshall & Rossman, 2011). To help reduce this issue of limited researcher perspective and to create clarity and consistency of coding the researcher completed interrater reliability procedures with members of her committee.

CHAPTER 4

Findings

Understanding what teachers in Grades 6-8 know and believe about science literacy or disciplinary literacy in science is the focus of this chapter, which describes participating teachers' conceptions of literacy, how it relates to science instruction, and how these conceptions compare across grade level contexts. With these purposes in mind, the chapter is organized into two main sections. The first section addresses teachers' knowledge and beliefs about science literacy and how these conceptions might differ according to teaching context (elementary or secondary). The second section describes participants' notions of instruction to support or develop science literacy.

Teachers' Knowledge and Beliefs about Science Literacy

With the goal of investigating how teachers in Grades 6-8 conceptualize and describe science literacy, or disciplinary literacy in science, participants were asked to respond to four questionnaire items: (1) What do you think of as literacy?, (2) What do you consider to be text?, (3) What types of text do you think of as being used in science?, and (4) What does science literacy mean to you? Findings related to each of these survey questions are included in the following subsections, first representing the entire population of participating teachers (Research Question #1), followed by comparisons across grade level contexts (Research Question #2). It should be noted that the number of coded instances exceeds the number of teachers who responded. This occurred because participant responses were often coded into multiple categories. For example, the participant response "Reading, writing, speaking, listening" was coded into two categories because not all participants included all four actions in their responses. The first coding instance, "Reading, writing," was included in the category *Reading and writing*, while the second coding instance for this teacher response, “speaking, listening,” was included in the coding category *Speaking and listening*. Additionally, it is important to note that when a response was unintelligible or absent, it was coded as *No response/Unclear*. (See Appendix E for a full list of the coding categories and their descriptions.)

The meaning of literacy. As depicted in Table 3, an overwhelming majority of all participating teachers’ responses included coded instances that fell into the *Reading and writing* coding category (i.e., read, write, grammar, comprehension, phonics, vocabulary, fluency), which essentially suggests that most participants hold traditional notions of literacy, as described by the National Institute of Child Health and Human Development (2000). The next two most frequent coding categories were *Communication* (i.e., a way to share ideas) and *Science literacy* (i.e., a way of knowing and communicating within the discipline of science), each with the same frequency. Interestingly, the following two coding categories also had similar frequencies: *Speaking and listening* (e.g., speak, listen, verbal) and *Tool to access the world* (i.e., being able to access information for personal use).

Table 3

Frequency and Percent of Teachers by Coding Category for Survey Question #1: Literacy

	Total teachers (n=235)		Elementary teachers Grade 6 (n=165)		Secondary teachers Grades 7-8 (n=70)	
Coding category	Frequency	Percent	Frequency	Percent	Frequency	Percent
Reading and writing	215	91.5	156	94.5	59	84.3
Communication	57	24.3	31	18.8	26	37.1
Science literacy	57	24.3	29	17.6	28	40.0
Speaking and listening	36	15.3	32	19.4	4	5.7
Tool to access the world	33	14.0	24	14.5	9	12.9
No response/unclear	4	1.7	4	2.4	0	0.0

Given the high frequency and percent of all participants who described literacy as *Reading and writing*, it is not surprising that this category represents the most commonly held belief about what literacy means, regardless of grade level context (see Table 3). Of note, however, secondary teachers were twice as likely as elementary teachers to understand literacy to be *Communication* or *Science literacy*. In contrast, elementary teachers described literacy as *Speaking and listening* three times more frequently than secondary teachers.

The meaning of text. As seen in Table 4, a majority of teachers' responses to survey question #2 suggested they conceptualize text as something *Read and written* (i.e., read, words, written, published/printed), which aligns with their beliefs about literacy (Table 3). This was true regardless of grade level context. Again, this suggests this population, overall, holds a traditional view of text (Keefe & Copeland, 2011).

Multiple modes (e.g., different ways to represent and present meaning such as visual representations or variety of genres of text) was the second most frequent response for all participating teachers. This again follows a pattern similar to that found in teachers' responses to the first survey question, where general notions about literacy, *Reading and writing*, are followed by a more domain-specific literacy idea, *Science literacy.* In the discipline of science, texts that teachers may utilize to develop science literacy contain various visual representations and are

Table 4

Frequency and Percent of Teachers by Coding Category for Survey Question #2: Text

	Total teachers (n=235)		Elementary teachers Grade 6 (n=165)		Secondary teachers Grades 7-8 (n=70)	
Coding category	Frequency	Percent	Frequency	Percent	Frequency	Percent
Read and written	208	88.5	146	88.5	62	88.6
Multiple modes	98	41.7	66	40.0	32	45.7
Conveys meaning	49	20.9	33	20.0	16	22.9
No response/unclear	3	1.3	3	1.8	0	0.0

written in a variety of genres (Airey & Linder, 2009; Coleman & Goldston, 2011; Deresz & Mattewson, 1982; Hand et al., 2003; Lemke, 1998; Norris & Phillips, 2003; NRC, 2012; Wellington & Osborne, 2001; Yore, Bisanz & Hand, 2010). Therefore, having *Multiple modes* as the second most frequent coding category for this question aligns with patterns seen in responses to survey question #1. Again, this did not differ significantly according to grade level context.

The meaning of science text. Eighty-six percent of all participants who responded to survey question #3 noted that *Informational texts* (e.g., nonfiction texts) are utilized during science instruction (Table 5). Yet again, participants' perceptions show a tendency to align with traditional views of expository or informational text being used in science, while recognizing that *Narrative texts* (e.g., texts written using fictional ideas) are not typically associated with science. This was even more pronounced with secondary teachers, where only two teachers suggested science text is narrative.

Additionally, although informational texts may contain symbolic representations, the coding category *Visual representations* (e.g., symbols, tables, graphs, captions, charts) also emerged as an important category with 30% of all participants recognizing that science text requires visual modes of representing ideas. This was true for nearly twice as many secondary teachers as elementary teachers. Response instances categorized as *Written* (i.e., texts must be written) were also found twice as frequently in secondary teachers' descriptions of science text as those of elementary teachers.

Table 5

Frequency and Percent of Teachers by Coding Category for Survey Question #3: Science Text

	Total teachers (n=235)		Elementary teachers Grade 6 (n=165)		Secondary teachers Grades 7-8 (n=70)	
Coding category	Frequency	Percent	Frequency	Percent	Frequency	Percent
Informational texts	202	86.0	145	87.9	57	81.4
Visual representations	71	30.2	39	23.6	32	45.7
Written	42	17.9	23	13.9	19	27.1
Narrative texts	17	7.2	15	9.1	2	2.9
Quiz/worksheets	12	5.1	7	4.2	5	7.1
No response/unclear	12	5.1	8	4.8	4	5.7

The meaning of science literacy. For survey question #4, only two major coding categories emerged (see Table 6). Within these two categories, approximately two-thirds of all teacher responses described science literacy as the *Integration of science and literacy* (i.e., science and literacy instruction happening simultaneously) or *General literacy* (i.e., skills associated with literacy such as read and write, speak and listen, vocabulary, comprehension). When the elementary and secondary teacher responses were considered separately for this question, secondary teachers were more likely to comment about *Integration of science and*

Table 6

Frequency and Percent of Teachers by Coding Category for Survey Question #4: Science Literacy

	Total teachers (n=235)		Elementary teachers Grade 6 (n=165)		Secondary teachers Grades 7-8 (n=70)	
Coding category	Frequency	Percent	Frequency	Percent	Frequency	Percent
Integration of science and literacy	152	64.7	98	59.4	54	77.1
General literacy	144	61.3	104	63.0	40	57.1
Science literacy	5	2.1	5	3.0	0	0.0
No response/unclear	6	2.6	5	3.0	1	1.4

literacy than elementary teachers, while response rates for *General literacy* were similar regardless of context.

Teachers' Knowledge and Beliefs about Quality Science Literacy Instruction

To explore teachers' ideas about quality instruction that supports or develops science literacy (Research Question #3), six instructional scenarios (survey items #5-10) were created according to criteria described in Appendix B. Two of these were developed as examples of instruction that is *Not authentic* (representing instruction that does not represent best practices in teaching science literacy); two were developed as examples of instruction that is *Partially authentic* (representing instruction that includes some elements that represent best practices in teaching science literacy); and two were developed as examples of *Authentic* instruction (representing best practices in teaching science literacy). Table 7 provides a brief summary of each of these scenarios in the order they were presented to the participating teachers.

As described previously, participants were asked to rate each scenario from 1 to 6, based on the authenticity of the instructional practices described. For ease in interpreting these ratings, the numerical values of 1-6 were grouped together into three categories representing the level of their authenticity: (a) 1 and 2: *Not authentic*, (b) 3 and 4: *Partially authentic*, and (c) 5 and 6: *Authentic*. In addition to rating each scenario, participants were asked to explain their ratings. As with other open response questions, participants' responses often resulted in multiple coding instances, thus representing more than one coding category.

Findings are provided in the subsections below by level of quality or authenticity in two ways: (a) for all participants by combined quality levels (*Not authentic, Partially authentic, Authentic*), and (b) as a comparison between elementary and secondary teaching context, as was done for Research Question #1 and Research Question #2.

Table 7

Summary of Science Literacy Instructional Scenarios by Number, Level of Science Literacy, and Description

Scenario number	Quality level of science literacy	Description
1	Not authentic	Students were asked to read text about gravity and celestial objects, write a Haiku or Cinquain poem, and create an illustration in the Impressionist style.
2	Authentic	Students began with a teacher generated question about the function of organelles within the whole structure of an organism. Students observed an online feed of organisms under an electron microscope, drew what they saw, paired with another student to compare their thinking to a textbook, and wrote their conclusions.
3	Partially authentic	Students were presented with lists of different celestial objects in the solar system organized according to diameter. They selected the list they thought was correct and researched online to determine if the objects were ordered correctly for size. Finally, students wrote an argument about the correctness of their list including a claim and evidence.
4	Authentic	Students were presented with a question and researched the answer using multiple sources. Based on their research, students planned an experiment to test their hypothesis and wrote an argument based on evidence from the findings that included visual representations.
5	Partially authentic	Students observed microorganisms in pond water under a microscope, then drew, read text, and took notes about the organisms in a graphic organizer. Students then wrote a summary about microorganisms based on their notes.
6	Not authentic	Students generated a KWL chart about Galileo's invention of the telescope as they either listened to or participated in a reader's theater presentation.

Not authentic scenarios. Scenarios #1 and #6 were designed to be examples of instruction that would not be considered best practices in developing science literacy because they do not ask children to engage in practices authentic to science. The quality level most frequently selected by all participating teachers for both of these scenarios was *Partially authentic* (see Table 8). Only 22% of participants (23% elementary; 20% secondary) considered the first of the *Not authentic* scenarios to be *Not authentic* (see Table 8) while 36% (30% elementary; 50% secondary) considered it to be *Authentic*. Interestingly, however, the order in which the scenarios appeared in the survey seemed to have altered some participants' perceptions of what constitutes best practices relative to developing science literacy, creating an

Table 8

Frequency and Percent of Teacher Responses by Combined Quality Rating and by Teaching Context for Instructional Scenarios

		Not authentic						Partially authentic						Authentic					
		Total teachers (n=235)		Elementary teachers (n=165)		Secondary teachers (n=70)		Total teachers (n=235)		Elementary teachers (n=165)		Secondary teachers (n=70)		Total teachers (n=235)		Elementary teachers (n=165)		Secondary teachers (n=70)	
Scenario	Quality level	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
1	NA	52	22.1	38	23.0	14	20.0	99	42.1	78	47.3	21	30.0	84	35.7	49	29.7	35	50.0
2	A	5	2.1	4	2.4	1	1.4	39	16.6	28	17.0	11	15.7	191	81.2	133	80.6	58	82.9
3	PA	8	3.4	6	3.6	2	2.9	55	23.4	48	29.1	7	10.0	172	73.2	111	67.3	61	87.1
4	A	3	1.3	2	1.2	1	1.4	24	10.2	20	12.1	4	5.7	208	88.5	143	86.7	65	92.9
5	PA	14	6.0	10	6.1	4	5.7	76	32.3	55	33.3	21	30.0	145	61.7	100	60.6	45	64.3
6	NA	75	31.9	51	30.9	24	34.3	104	44.3	74	44.8	30	42.9	56	23.8	40	24.2	16	22.9

"order effect" (Strack, 1992). By the time teachers were asked to rate the second of the *Not authentic* scenarios, they had read and rated two *Partially authentic* and two *Authentic* scenarios and seemed to have changed their perceptions of instruction authentic to science. Thus, when asked to rate the second *Not authentic* scenario, 32% (31% elementary; 34% secondary) of participants recognized it as not representative of practices authentic to science, while only 24% (24% elementary; 23% secondary) of participants rated it as *Authentic*.

Not authentic rating explanations. For both *Not authentic* scenarios, the most frequently reported explanations for rating them as *Not authentic* were that these scenarios did not represent instruction authentic to science. Teachers suggested they were *Not science literacy* (e.g., lacks ways of knowing and communicating authentic to the discipline of science) and *Poor instructional strategies* (e.g., instructional strategies generally thought to be ineffective at facilitating student understanding) (see Tables 9 & 10). One-third of participating teachers' explanations, who selected this rating, also suggested that the *Integration does not work* (e.g., art instruction does not improve science instruction).

Elementary teachers were more likely than secondary teachers to explain that these scenarios represented *Poor instructional strategies* (45% elementary; 29% secondary), while secondary teachers were more likely to suggest that the scenarios were *Not science literacy* (24% elementary; 93% secondary) in the first *Not authentic* scenario. Otherwise, reasons for their ratings were similar across elementary and secondary teacher explanations.

Partially authentic rating explanations. Teachers who selected a *Partially authentic* rating for the *Not authentic* scenarios cited *Poor instructional strategies* as a major reason for

Table 9

Frequency and Percent of All Teacher Responses by Coding Category for Each Quality Group as a Total and by Teaching Context for Scenario #1: Not Authentic Science Literacy

	Not authentic						Partially authentic						Authentic					
	Total teachers (n=52)		Elementary teachers (n=38)		Secondary teachers (n=14)		Total teachers (n=99)		Elementary teachers (n=78)		Secondary teachers (n=21)		Total teachers (n=84)		Elementary teachers (n=49)		Secondary teachers (n=35)	
Coding category	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Integrates arts	10	19.2	8	21.1	2	14.3	44	44.4	33	42.3	11	52.4	54	64.3	41	83.7	13	37.1
Poor instructional strategies	21	40.4	17	44.7	4	28.6	43	43.4	39	50.0	4	19.0	12	14.3	7	14.3	5	14.3
Not science literacy	22	42.3	9	23.7	13	92.9	24	24.2	20	25.6	4	19.0	3	3.6	1	2.0	2	5.7
Good instructional strategies	0	0.0	0	0.0	0	0.0	9	9.1	4	5.1	5	23.8	37	44.0	20	40.8	17	48.6
Integration does not work	17	32.9	12	31.6	5	35.7	16	16.2	9	11.5	7	33.3	3	3.6	2	4.1	1	2.9
General literacy	3	11.5	3	7.9	0	0.0	20	20.2	16	20.5	4	19.0	11	13.1	7	14.3	4	11.4
Science literacy	2	3.8	2	5.3	0	0.0	0	0.0	0	0.0	0	0.0	1	1.2	1	2.0	0	0.0
No response/unclear	1	1.9	1	2.6	0	0.0	4	4.0	4	5.1	0	0.0	10	11.9	6	12.2	4	11.4

Table 10

Frequency and Percent of All Teacher Responses by Coding Category for Each Quality Group as a Total and by Teaching Context for Scenario #6: Not Authentic Science Literacy

	Not authentic						Partially authentic						Authentic					
	Total teachers (n=75)		Elementary teachers (n=51)		Secondary teachers (n=24)		Total teachers (n=104)		Elementary teachers (n=74)		Secondary teachers (n=30)		Total teachers (n=56)		Elementary teachers (n=40)		Secondary teachers (n=16)	
Coding category	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Poor instructional strategies	37	49.3	24	47.1	13	54.2	51	49.0	35	47.3	16	53.3	10	17.9	10	25.0	0	0.0
Not science literacy	33	44.0	22	43.1	11	45.8	20	19.2	17	23.0	3	10.0	4	7.1	4	10.0	0	0.0
General literacy	12	16.0	10	19.6	2	8.3	15	14.4	10	13.5	5	16.7	16	28.6	8	20.0	8	50.0
Good instructional strategies	3	4.0	2	3.9	1	4.2	16	15.4	11	14.9	5	16.7	22	39.3	17	42.5	5	31.3
Integrates arts	1	1.3	1	2.0	0	0.0	13	12.5	8	10.8	5	16.7	9	16.1	9	22.5	0	0.0
Limited general literacy	2	2.7	1	2.0	1	4.2	9	8.7	6	8.1	3	10.0	1	1.8	1	2.5	0	0.0
No Response/ Unclear	4	4.0	3	5.9	1	4.2	12	11.5	8	10.8	4	13.3	11	19.6	7	17.5	4	25.0

their rating (50% elementary;19% secondary). This was the most frequent explanation provided for the second *Not authentic* scenario. *Not science literacy* (23% elementary; 10% secondary) was also mentioned more frequently by teachers when explaining their ratings for the second *Not authentic* scenario.

Interestingly, when rating the first *Not Authentic* scenario as *Partially authentic*, *Integrates arts* (e.g., art is used to facilitate science instruction and/or art and science are being taught at the same time) was the most frequent explanation provided by both elementary and secondary teachers. *Not science literacy* and *General literacy* (i.e., skills associated with literacy such as read and write, speak and listen, vocabulary, comprehension) appeared in about 20% of teachers' explanations for their ratings.

Authentic rating explanations. Perhaps not surprisingly, teachers who selected an *Authentic* quality level rating for these *Not Authentic* scenarios often suggested that they demonstrated *Good instructional strategies*. However, the reasons teachers provided were somewhat different by scenario. *Integrates arts* was the most frequent reason provided by teachers for their rating of the first of these scenarios as high quality or *Authentic* (84% elementary; 37% secondary). For the second *Not authentic* scenario, 50% of secondary and 20% of elementary participating teachers also noted that it represented *General literacy* practices.

Partially authentic scenarios. Scenarios #3 and #5 were designed to be examples of instruction that contain some elements that would be considered to be best practices in developing science literacy because they ask children to engage in practices that are authentic to science in some regards but not in all aspects. The quality level most frequently selected by all participating teachers for both of these scenarios was *Authentic* (see Table 8). Only 23% of participants (29% elementary; 10% secondary) considered the first of the *Partially authentic* scenarios to be *Partially authentic* (see Table 8). As was observed with the *Not authentic* scenarios where participants' ratings rose from 22% (Scenario #1) to 32% (Scenario #6) for the designed scenario rating, order effect (Strack, 1992) may also be an issue in the *Partially authentic* scenarios (23% Scenario #3; 32% Scenario #5). This may be particularly true for secondary teachers. After reading one *Not authentic* scenario and two *Authentic* scenarios, teachers' ratings changed from 10% in Scenario #3 to 30% in Scenario #5. Overall, though, 62% (61% elementary; 64% secondary) of participants still rated these *Partially authentic* scenarios as *Authentic*.

Partially authentic rating explanations. For the first *Partially authentic* scenario, the most frequently reported explanations for rating them as *Partially authentic* were that these scenarios did represent instruction authentic to science. Thus, teachers suggested they were *Science literacy* (i.e., a way of knowing and communicating within the discipline of science), and *Good instructional strategies* (see Table 11). However, one-third of teachers' explanations for those who selected this rating also included *Poor instructional strategies* or how instruction did not represent best teaching practices. Interestingly, secondary teachers were more likely than elementary teachers to provide these reasons in their explanations: *Science literacy* (27% elementary; 100% secondary), *Good instructional practices* (33% elementary; 86% secondary), and *Poor instructional strategies* (29% elementary; 57% secondary).

The second-time teachers were asked to rate a *Partially authentic* scenario, the most frequent explanations for rating it as *Partially authentic* changed to suggest these scenarios did not represent instruction authentic to science. This time more teachers noted that the instruction described did not represent best practices in developing science literacy, suggesting it was *Not*

Table 11

Frequency and Percent of All Teacher Responses by Coding Category for Each Quality Group as a Total and by Teaching Context for Scenario #3: Partially Authentic Science Literacy

	Not authentic						Partially authentic						Authentic					
	Total teachers (n=8)		Elementary teachers (n=6)		Secondary teachers (n=2)		Total teachers (n=55)		Elementary teachers (n=48)		Secondary teachers (n=7)		Total teachers (n=172)		Elementary teachers (n=111)		Secondary teachers (n=61)	
Coding category	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Science literacy	0	0.0	0	0.0	0	0.0	20	36.4	13	27.1	7	100.0	124	72.1	84	75.7	40	65.6
Good instructional strategies	2	25.0	1	16.7	1	50.0	22	40.0	16	33.3	6	85.7	80	46.5	62	55.9	18	29.5
General literacy	0	0.0	0	0.0	0	0.0	4	7.3	2	4.2	2	28.6	32	18.6	24	21.6	8	13.1
Poor instructional strategies	4	50.0	2	33.3	2	100.0	18	32.7	14	29.2	4	57.1	5	2.9	4	3.6	1	1.6
Integrates arts	0	0.0	0	0.0	0	0.0	1	1.8	1	2.1	0	0.0	17	9.9	17	15.3	0	0.0
Not science literacy	0	0.0	0	0.0	0	0.0	5	9.1	3	6.3	2	28.6	5	2.9	2	1.8	3	4.9
No Response/Unclear	0	0.0	0	0.0	0	0.0	2	3.6	2	4.2	0	0.0	11	6.4	8	7.2	3	4.9

Science literacy and *Poor instructional strategies* (see Table 12). Additionally, a smaller percentage (20%) of teachers mentioned *General literacy* as an explanation for their rating. Additionally, in contrast to the first *Partially authentic* scenario, a slightly higher percentage of elementary teachers explained that this scenario was *Not science literacy* (35% elementary; 24% secondary) and represented *Poor instructional strategies* (29% elementary; 24% secondary) as compared to secondary teachers.

Not authentic rating explanations. Teachers who selected a *Not authentic* rating for the *Partially authentic* scenarios cited *Poor instructional strategies* as a major reason for their rating in both scenarios. *Not science literacy* was also frequently noted in teachers' explanations for this scenario. Of note, relatively few teachers (Scenario #3=8, Scenario #5=14) rated the two *Partially authentic* scenarios as *Not authentic.*

Authentic rating explanations. As may be expected, teachers who selected an *Authentic* quality level rating for the first of these scenarios suggested that it demonstrated *Science literacy* (72%) and *Good instructional strategies* (47%). The frequency of these reasons in teachers' explanations, however, dropped for the second scenario (30% *Science literacy*; 31% *Good instructional strategies*), while *General literacy* rose (first scenario=19%; second scenario=36%).

Authentic scenarios. Scenarios #2 and #4 were designed to be examples of instruction that would be considered best practices in developing science literacy because they ask children to engage in practices authentic to science. The quality level most frequently selected by all participating teachers for both of these scenarios was *Authentic* (see Table 8) the same as the designed quality level. Overwhelmingly, 81% of participants (81% elementary; 83% secondary) considered the first of the *Authentic* scenarios to be *Authentic* (see Table 8). Interestingly,

Table 12

Frequency and Percent of All Teacher Responses by Coding Category for Each Quality Group as a Total and by Teaching Context for Scenario #5: Partially Authentic Science Literacy

	Not authentic						Partially authentic						Authentic					
	Total teachers (n=14)		Elementary teachers (n=10)		Secondary teachers (n=4)		Total teachers (n=76)		Elementary teachers (n=55)		Secondary teachers (n=21)		Total teachers (n=145)		Elementary teachers (n=100)		Secondary teachers (n=45)	
Coding category	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
General literacy	0	0.0	0	0.0	0	0.0	15	19.7	11	20.0	4	19.0	52	35.9	35	35.0	17	37.8
Science literacy	1	7.1	0	0.0	1	25.0	10	13.2	7	12.7	3	14.3	43	29.7	32	32.0	11	24.4
Good instructional strategies	1	7.1	0	0.0	1	25.0	7	9.2	4	7.3	3	14.3	45	31.0	34	34.0	11	24.4
Integrates arts	0	0.0	0	0.0	0	0.0	9	11.8	6	10.9	3	14.3	32	22.1	23	23.0	9	20.0
Not science literacy	7	50.0	5	50.0	2	50.0	24	31.6	19	34.5	5	23.8	11	7.6	8	8.0	3	6.7
Poor instructional strategies	7	50.0	6	60.0	1	25.0	21	27.6	16	29.1	5	23.8	14	9.7	9	9.0	5	11.1
Limited general literacy	0	0.0	0	0.0	0	0.0	3	3.9	3	5.5	0	0.0	1	0.7	0	0.0	1	2.2
No Response/Unclear	1	7.1	0	0.0	1	25.0	5	6.6	4	7.3	1	4.8	17	11.7	12	12.0	5	11.1

however, order effect may have again affected some participants' perceptions of what constitutes best practices relative to developing science literacy. By the time they rated the second of the *Authentic* scenarios, they had read and rated one *Not authentic* and one *Partially authentic* scenario and seemed to have adjusted their knowledge and beliefs about what constitutes best practices in developing science literacy. Thus, for the second *Authentic* scenario, 89% (87% elementary; 93% secondary) of participants recognized it was representative of practices authentic to science.

Authentic rating explanations. For both *Authentic* scenarios, the most frequently reported explanations for rating them *Authentic* were that these scenarios did represent best practices in teaching science literacy. Thus, teachers suggested they were *Science literacy*, *Good instructional strategies*, and *General literacy* (see Tables 13 & 14). Additionally, one-third of participating teachers' explanations also suggested that *Integration does not work* (e.g., art instruction does not improve science instruction).

Elementary teachers were more likely than secondary teachers to explain that these scenarios represented *Good instructional strategies* (60% elementary; 33% secondary) and *General literacy* (49% elementary; 25% secondary). Meanwhile, secondary teachers were more likely to suggest that the scenarios were *Science literacy* (52% elementary; 63% secondary).

Not authentic rating explanations. Very few teachers selected a *Not authentic* rating for both the first (elementary=4; secondary=1) and the second (elementary=2; secondary=1) *Authentic* scenarios. Because of the low numbers of teachers selecting this rating, the reasons for their rating are not discussed.

Partially authentic rating explanations. Teachers' reasons for selecting a *Partially authentic* quality level rating differed by scenario. For the first scenario, teachers as a group

Table 13

Frequency and Percent of All Teacher Responses by Coding Category for Each Quality Group as a Total and by Teaching Context for Scenario #2: Authentic Science Literacy

	Not authentic						Partially authentic						Authentic					
	Total teachers (n=5)		Elementary teachers (n=4)		Secondary teachers (n=1)		Total teachers (n=39)		Elementary teachers (n=28)		Secondary teachers (n=11)		Total teachers (n=191)		Elementary teachers (n=133)		Secondary teachers (n=58)	
Coding category	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Good instructional strategies	1	20.0	0	0.0	1	20.0	9	23.1	8	28.6	1	9.1	115	60.2	79	59.4	36	62.1
Science literacy	2	40.0	2	40.0	0	0.0	7	17.9	5	17.9	2	18.2	99	51.8	76	57.1	23	39.7
General literacy	0	0.0	0	0.0	0	0.0	10	25.6	6	21.4	4	36.4	94	49.2	61	45.9	33	56.9
Poor instructional strategies	1	20.0	1	20.0	0	0.0	16	41.0	14	50.0	2	18.2	10	5.2	3	2.3	7	12.1
Not science literacy	0	0.0	0	0.0	0	0.0	5	12.8	3	10.7	2	18.2	6	3.1	6	4.5	0	0.0
Integrates arts	0	0.0	0	0.0	0	0.0	1	2.6	1	3.6	0	0.0	6	3.1	6	4.5	0	0.0
Integration does not work	1	20.0	1	20.0	0	0.0	2	5.1	1	3.6	1	9.1	1	0.5	0	0.0	1	1.7
No Response/Unclear	0	0.0	0	0.0	0	0.0	4	10.3	2	7.1	2	18.2	13	6.8	8	6.0	5	8.6

Table 14

Frequency and Percent of All Teacher Responses by Coding Category for Each Quality Group as a Total and by Teaching Context for Scenario #4: Authentic Science Literacy

	Not authentic						Partially authentic						Authentic					
	Total teachers (n=3)		Elementary teachers (n=2)		Secondary teachers (n=1)		Total teachers (n=24)		Elementary teachers (n=20)		Secondary teachers (n=4)		Total teachers (n=208)		Elementary teachers (n=143)		Secondary teachers (n=65)	
Coding Category	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Science literacy	1	33.3	0	0.0	1	33.3	7	29.2	6	30.0	1	25.0	130	62.5	89	62.2	41	63.1
Good instructional strategies	2	66.7	2	66.7	0	0.0	8	33.3	7	35.0	1	25.0	69	33.2	54	37.8	15	23.1
General literacy	0	0.0	0	0.0	0	0.0	2	8.3	2	10.0	0	0.0	53	25.5	39	27.3	14	21.5
Integrates arts	0	0.0	0	0.0	0	0.0	1	4.2	1	5.0	0	0.0	18	8.7	18	12.6	0	0.0
Too hard/ Takes too long	0	0.0	0	0.0	0	0.0	6	25.0	3	15.0	3	75.0	10	4.8	6	4.2	4	6.2
Poor instructional strategies	0	0.0	0	0.0	0	0.0	4	16.7	4	20.0	0	0.0	8	3.8	6	4.2	2	3.1
Diverts focus from science	0	0.0	0	0.0	0	0.0	1	4.2	1	5.0	0	0.0	2	1.0	1	0.7	1	1.5
No Response/Unclear	0	0.0	0	0.0	0	0.0	3	12.5	2	10.0	1	25.0	18	8.7	12	8.4	6	9.2

suggested *General literacy* (26%) as the most frequent explanation for their rating. However elementary teachers provided two reasons with more frequency: *Good instructional strategies* (29% elementary; 9% secondary) and *Poor instructional strategies* (50% elementary; 18% secondary). For the second scenario, the two explanations all teachers offered most frequently for rating it as *Partially authentic* were *Good instructional strategies* (33%) and *Science literacy* (29%).

CHAPTER 5

Discussion

The purpose of this study was to gain insight into what teachers in grades 6-8 know and believe about science literacy, including their conceptions of literacy and how they relate to developing science literacy during science instruction. The study also sought to explore how participants' conceptions compare across grade level contexts. This chapter includes a discussion of the conclusions and implications of the study, along with recommendations for future research.

Teachers' Knowledge and Beliefs about Science Literacy

This section discusses research findings regarding participating teachers' knowledge and beliefs about literacy, text, science literacy, and science text within two subsections (a) literacy and text and (b) science literacy and science text. These findings are examined in relation to existing literature.

Teachers' knowledge and beliefs about literacy and text. Overall, and perhaps not surprisingly, most participating teachers, despite their teaching context, appear to maintain a traditional view of literacy (92%) and text (89%). This suggests that (a) these teachers understand literacy to involve reading and writing, (b) being literate is being able to read and write (Hodges, 1999), and (c) text is language that is recorded in written form (Siebert & Draper, 2008), a definition that has been in common use for over 500 years. Additionally, it has been promoted over time by prominent organizations, such as the National Reading Panel (2000), the National Institute of Child Health and Human Development (2000), and the United Nations Educational, Scientific, and Cultural Organization (2008).

Fewer participants, secondary teachers (37%) in particular, seem to conceive of literacy more comprehensively, as communication. This suggests they understand literacy or being literate as an interaction or transmission of information (using a variety of modalities and genres) between a sender and a receiver, where meanings are conveyed and understood (McQuail, 2008). Again, participating teachers hold a common conceptualization of literacy, which has been promoted for over two decades by both literacy and science educators (Hodge, 1999; Keefe & Copeland, 2011; NRC, 1996; NRC, 2012; Position Statement of the IRA, 2012).

More recently, new state science education standards for Grades 6-8 were adopted for the 2017-2018 school year that embed communication within the scientific and engineering practices as a critical component of science instruction for all students because "communicating in written or spoken form is…a fundamental practice of science" (NRC, 2012, p. 74). While thinking about communication or meaning sharing as a "fundamental practice" in which scientists engage and one students should become familiar with during their K-12 experience (Lemke, 2001) may be relatively new to many elementary teachers, secondary teachers may be more inclined to view literacy through this lens of communication as it is familiar to them as members of a science-centered community of practice (Wenger, 1998).

More secondary teachers (40%) also described aspects of science literacy as part of their definition of literacy. Again, this may be due to their having been enculturated into a particular community of practice (Wenger, 1998) wherein they have learned to conceptualize and use communicative practices connected to community norms. In other words, perhaps because of their discipline-specific preparation in science, many participating secondary teachers seemed to more closely identify with the communicative practices of science. Given this affiliation, it may, be surprising that more secondary teachers did not use this language when defining literacy.

Nearly half of all participating teachers also indicated that text includes representations beyond traditional print, indicating that multiple modes are used in communicating ideas or messages (see Kress, 2010) in science. These include visual, linguistic, or actional representations, including images, numbers, spoken and written words, models, and so forth (Airey & Linder, 2009; Jewitt, Kress, Ogborn & Tsatsarelis, 2001). This could be attributed to the long-term influence of the *National Science Education Standards* (NRC, 1996) and the Intended Learning Outcomes (ILOs) for grades 3-12 which are included in the state science standards (Utah State Office of Education, 2002) where, for example, students are expected to "record data accurately when given the appropriate form and format" (Utah State Office of Education, 2002, ILOs for Third Grade Science). This would suggest that students are creating charts, graphs, tables, etc.

Teachers' knowledge and beliefs about science literacy and science text. When participating teachers were asked to describe science literacy, a majority did so in two distinct ways. First, it appears that over half of the teachers view science literacy as an integration of science and literacy: that teachers make an instructional decision to teach the two disciplines at the same time (see Hall-Kenyon & Smith, 2013). Second, over half of the participants also view science literacy as general literacy: that it is a set of traditional reading and writing skills (National Academy of Sciences, 2016). In either case, these teachers seem to understand science literacy as having only a "functional relationship with respect to science, as simply tools for the storage and transmission of science" (Norris & Phillips, 2003, p. 226).

In contrast, Norris and Phillips (2003) argue that the ability to read and write in science is only one aspect, or sense, of what is necessary to being science literate and refer to "reading and writing when the content is science" (p. 224) as the *fundamental* sense of science literacy. The other sense, the *derived sense*, includes "being knowledgeable, learned, and educated in science" (p. 224). However, and importantly, they argue that these two senses cannot be separated as there is a "constitutive relationship" between them (Norris & Phillip, 2003). Thus, participating teachers' conceptions of science literacy as general literacy or an "integration" of science and literacy may be naïve, uninformed, or undeveloped and arise from a lack of understanding that science subject matter knowledge and communicative practices are both "essential elements of the whole" (Norris & Phillips, 2003, p. 226). Or, it may be that the term, science literacy, is simply unfamiliar to participating teachers. Further research, involving more qualitative methods, including interview and/or classroom observations is needed to accurately understand participates' reasoning behind the responses they offered in regard to science literacy.

Teachers also may view text used in science from a functional perspective given their descriptions included the notion that science text is informational (86%), not narrative (7%). It is as if the text's function in science, to receive or express meaning of information, determined that the genre was informational. For elementary teachers, who are responsible for teaching all academic subjects, this idea may, in part, be a response to current ELA reading standards, which are separated into two distinct categories: (a) reading literature and (b) reading information (NGA & CCSSO, 2010). However, the response was equally high for both elementary and secondary teachers. This may be due to a current, politically charged notion that instruction in STEM subjects should include the arts or STEAM (English, 2017; Guyotte et al., 2015). Integrating the arts as part of STEM instruction is currently promoted as not only appropriate and important, but as a way to deepen learning (English, 2017; Guyotte et al., 2015). However, this can be problematic because the informational text genre is so broad that it could include any text "written with the primary purpose of conveying information about the natural and social world"

(Duke, 2000, p. 205). Thus, instead of interpreting the integration of art and science in ways authentic to the discipline of science, the potential is also open for the arts to be integrated in ways inauthentic to science. For example, poetry that contains accurate scientific information could be considered informational text and an appropriate form of communication. However, scientists do not generally utilize poetry as a form of communication in their work (NRC, 2012). Authentic communication in the discipline of science suggests the use of a limited subset of informational texts, including science textbooks, research journals, field notes, emails, newspapers, magazines, blogs, websites, etc. (Hand et al., 2003; NRC, 2012; Moje, 2015; Yore, Bisanz, & Hand, 2010). This suggests that using the term *informational text* to describe science text may be too broad or general to adequately define the types of text scientists actually utilize.

The notion that science text is simply any form of informational text also seems to run counter to present and prior science and ELA standards. Currently, the ELA standards include a section for reading and writing in science and technical subjects for Grades 6-12 (NGA & CCSSO, 2010). For reading science, these skills include "distinguishing among facts and reasoned judgement based on research findings, comparing information gained from experiments, following a multistep procedure, and taking measurements" (NGA & CCSSO, 2010). In these examples, the skills clearly indicate the use of a specific subset of informational text. However, it is doubtful that secondary science teachers would be familiar with these standards and their content because they have been written for English language arts teachers. Such documents are not those that typically influence the thinking or practice of secondary science teachers.

That science utilizes specific types of informational text is also noted in the new state science standards for Grades 6-8. By following these standards, "students are guided—or apprenticed—into the fundamental practices of [science]" (Schwarz, Passmore & Reiser, 2017, p. 312). These practices (e.g., planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argument from evidence) require the use of discipline-specific types of informational text (NRC, 2012).

Previous science standards also noted that certain texts are appropriate for science. For example, according to these standards, students would be expected to learn to "record data accurately when given the appropriate form (e.g., table, graph, chart)…describe or explain observations carefully and report with…sentences and models…[and] use mathematical reasoning to communicate information" (Utah State Office of Education, 2002, ILOs for Fifth Grade Science). Again, this suggests the text used in science for receiving and expressing meaning is a specialized subset of informational text (Airey & Linder, 2009; Coleman & Goldston, 2011; Lemke, 1998; NRC, 2012; Yore, Bisanz & Hand, 2010).

Interestingly, a significant number of secondary teachers (46%), specify that science text contains visual representations (e.g., numbers, symbols, graphs, and charts), which are specific types of texts that convey concepts or ideas (information) within the discipline of science (Airey & Linder, 2009; NRC, 2012). Thus, it is likely that the secondary teachers who identified text in science as informational (81%) were thinking of these types of text. Again, further research is needed to accurately determine teachers' definitions of informational text and their reasons for those definitions.

Teachers' Knowledge and Beliefs About Quality Instruction that Develops Science Literacy

Overall, teachers tended to rate all of the scenarios high, suggesting they believe all of the descriptions represented instruction that would support the development of science literacy. For example, in the first *Not authentic* example, Scenario #1, three-fourths of teachers rated the scenario higher than the designed rating. The explanation most frequently cited by teachers for selecting a higher rating in this situation was integrates arts even though the integration of literacy and visual arts did not support the development of science content knowledge or a sense of the nature of science. Nor did it engage students in communicative practices authentic to science. It seems participating teachers may view any decision to integrate as an improvement in the quality of instructional practice. It is as if integration is considered an "unqualified good" (Hall-Kenyon & Smith, 2013, p. 96). This may not be surprising given some previous research has promoted this idea (Sen & Ay, 2017; Switzer & Voss, 1982). Other research has also indicated that integration increases student achievement (Berlin & Hillen, 1994; Hurley, 2001). However, it has also been documented that integrating two disciplines during instruction in an effective manner is challenging because definitions of what integration actually entails vary widely and ideas about implementation differ drastically (Hall-Kenyon & Smith, 2013). Moreover, successfully integrating two or more disciplines requires extensive content knowledge and deep understanding of pedagogy in each of the disciplines (Hall-Kenyon & Smith, 2013). Thus, teachers who suggested that the integration described in this scenario increased the instructional quality and the development of science literacy may not have a clear understanding of what it means to be literate in science (Norris & Phillips, 2003). Their explanation may also be attributed to recent efforts across the participating districts to incorporate the arts into the teaching of the STEM disciplines (i.e., STEAM education) despite questionable or "thin" evidence that doing so improves learning in science (Daugherty, 2013), as was previously discussed in this chapter.

Another interesting finding was that a large majority of teachers were successful when presented with examples that exemplify best practices in teaching science literacy but could not discriminate levels of quality when examples included minimal or no elements considered to be best practices. Indeed, a large majority of teachers selected *Authentic* as their rating of both *Authentic* scenarios. Thus, while it appears that a majority of Grade 6-8 teachers in this study recognize or sense that instruction that incorporates both senses of science literacy (Norris & Phillps, 2003) represents good practice, they may not have enough explicit understanding to identify exactly what it is that makes instruction good or not. As a result, the most frequent explanations were fairly generic: good instructional strategies and poor instructional strategies instead of more explicit reasons such as science literacy or not science literacy.

It may also be possible that many of these teachers, particularly secondary teachers whose definitions of "literacy" were consistent with an appropriate definition of "science literacy," may be unfamiliar with the terminology used in the study. In other words, they may never have been introduced to the term, science literacy, or its definition. Thus, simply familiarizing them with the terms used in science education should be helpful.

Another finding occurred due to a "fortunate" oversight in methodology. Because the order of the scenarios that teachers viewed and rated was the same for all participants, it was possible to examine how this order might have influenced teachers' thinking about best teaching practices in science literacy. Interestingly, teachers' understanding of what is involved in instruction designed to support students' development of science literacy improved as they were presented with scenarios that described different levels of quality. Thus, the percentage of teachers rating each scenario the same as the designed quality level (i.e., *Authentic, Partially authentic, Not authentic*) rose from the first time they rated a scenario in a given quality level to the second time. Although this happened for each of the three quality levels for both elementary and secondary teachers, the effect was stronger for secondary teachers. This may again be a product of secondary teachers' identification with a familiar science-centered community of practice (Wenger, 1998). They may have resonated with activities and communicative practices more authentic to what they had experienced as they worked in laboratories or field experiences in learning science.

Conclusion and Implications

The results of this study suggest that participating teachers "who are responsible for science have not been provided with the knowledge and skills required to teach…in science education" (NRC, 2014, p. 13). This may be because past science education standards and teacher education programs for both intending and practicing teachers tended to "emphasize discrete facts with a focus on breadth over depth" (NRC, 2014, p. 11). At the same time, these teacher resources failed to help teachers understand the inextricable nature of the content of science (the knowledge of science facts, concepts, theories, laws) and the practices involved in coming to know and communicate in science. Indeed, the Intended Learning Outcomes, which describe the skills and ways of thinking scientists utilize and those we would want students to access, was included separately from the science subject matter knowledge in previous and long-standing state science standards (Utah State Office of Education, 2002). This organization may have suggested to teachers that knowledge and skills are separate entities in science literacy instruction and not intertwined as Norris & Phillips (2003) suggest. In fact, research shows that curriculum materials utilized in U.S. classrooms tend to focus mainly on memorizing factual information and minimizing the utilization of science practices (Schwarz, Passmore & Reiser, 2017). These foci severely limit students in engaging in authentic science experiences that develop science literacy (NRC, 2014).

The Framework (NRC, 2012) emphasizes these shortcomings in science education, noting that "K-12 science education is generally too disconnected from the way science and engineering are practiced and should be reformed" (NRC, 2014, p. 13). As a result, newly adopted national science education standards appear to be more focused on helping teachers provide K-12 students with more authentic science experiences. The hope is that teachers will "take advantage of the research-based recommendations in the framework for making science learning more meaningful and effective for all students" (Schwarz, Passmore & Reiser, 2017, p. 4). While these new standards do not prescribe *how* to teach, they do provide teachers "clear direction for what [they] should be aiming for in [their] science instruction" (p. 5) as they prepare students to live and work in a global society where science "permeate[s] every aspect of modern life" (NRC, 2012, p. 7).

In order for teachers to gain an understanding of how science literacy might be more effectively developed through implementation of the new standards, teacher preparation programs and professional development should provide learning experiences that help preservice and practicing teachers better understand the importance of teaching both science subject matter knowledge as well as the communicative practices used in science and how scientists come to know. For both in-service and preservice teachers, these opportunities should include providing explicit instruction about both the *fundamental* and *derived senses* (Norris & Phillips, 2003) of science literacy. Also, explanations of how these senses are inherent in the three dimensions of science education (NGSS Lead States, 2013: NRC, 2012) will help teachers more fully recognize how these aspects of being science literate actually work within the discipline of science and how they might better help students come to understand them. Additionally, along with engaging teachers in learning activities that enable them to develop science literacy, providing them with clear descriptions and classroom scenarios that demonstrate best practices in teaching science literacy may help them understand how a science-centered community receives and expresses meaning within specific instructional contexts. In other words, viewing scenarios could build their own ability to identify with a science community of practice and enable them to provide such access to their students.

With this emphasis in mind, teachers can gain understanding about what quality instruction for developing science literacy entails so that instruction "closely mirrors the way that science is practiced and applied" (NRC, 2014, p. 11). This will, in turn, help students develop science literacy so they can more easily engage in fields related to the discipline of science in college and careers (NRC, 2012, p. 1) if they so choose. They will also have the ability to become informed citizens in the decisions they make throughout their lives (National Academy of Sciences, 2016).

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APPENDIX A

Questions for Initial Questionnaire

Part One (Research Study Questions)

1. What do you think of as literacy?

2. What do you consider to be text?

3. What types of text do you think of as being used in science?

4. What does science literacy mean to you?

   Questions 5-10 contain a variety of teaching scenarios. For each question, rate the teaching scenario from 1 - 6 with 6 demonstrating the **highest** level of best practices in teaching science literacy and 1 demonstrating the **lowest** level of best practices in teaching science literacy:

5. Students independently read a section in a science textbook that describes how force is used to hold celestial objects in orbit around larger objects of greater mass in the solar system. Based on the information in the textbook, each student is asked to create a Haiku or Cinquain poem that describes the role of gravity on the orbits of the earth and the moon in our solar system. Because the students have been learning about the Impressionist style and the works of the artists Monet and Renoir during art instruction, they are also asked to illustrate their poem using watercolors.

   Please select one rating (1-6) for this scenario and provide a brief explanation for why you rated the scenario the way you did:

6. The teacher asks the question, "How do the individual organelles in a Euglena (protist) contribute to the function of the whole organism?" Students observe a video of Euglena under an electron microscope. They use a computer application to draw a model of a Euglena, label the organelles, and note the organelles' functions within the whole organism. In pairs, students compare their models and note discrepancies. The pairs then compare their models to a model of a Euglena found in a science textbook, revise their descriptions of organelle functions where appropriate, and write an explanation of how the individual organelles contribute to the function of the whole organism.

   Please select one rating (1-6) for this scenario and provide a brief explanation for why you rated the scenario the way you did:

7. Each student in a class is given six lists of celestial objects found in the solar system that are ordered according to size. Some lists are accurate and others are not. Each student choses one list that is correct and makes a claim as to why the objects are accurately classified. Students are then placed into groups of five. Within the group they discuss

their claims, select one claim to research, and use technology to access online resources to justify their group's claim. After researching, students write an argument agreeing or disagreeing with their original claim based on the evidence they found.

Please select one rating (1-6) for this scenario and provide a brief explanation for why you rated the scenario the way you did:

8. Students are asked the question, "What do living organisms need to survive?" In groups of four, students find and use multiple resources to research an answer to the question. As a group, they write a claim based on information from credible sources of science text. Then, they design an investigation to test their claim, conduct the investigation, compile their findings and display the information in a table and/or graph, and write an argument based on their claim. The argument contains conclusions based on evidence found as a result of their investigation and supported by credible sources.

   Please select one rating (1-6) for this scenario and provide a brief explanation for why you rated the scenario the way you did:

9. In the classroom, students observe producer and consumer microorganisms that are commonly found in pond water under a microscope (e.g., Paramecium, Amoeba, Euglena, Algae). After completing the observation, students draw examples of the microorganisms. Then, as a class they read a science text that describes the characteristics of producer and consumer microorganisms. While they read, students record information in a concept web graphic organizer because they are studying text structures as a way to improve comprehension. Finally, each student writes a summary of the text utilizing the information in the graphic organizer while also including details from the microorganism observation.

   Please select one rating (1-6) for this scenario and provide a brief explanation for why you rated the scenario the way you did:

10. The students are taught that a variety of instruments are used to investigate the moon and planets in the solar system. Some students in the class are assigned a part to read in a reader's theater presentation that discusses Galileo's life as a scientist, making sure they read with appropriate rate and expression. The rest of the students in the class are asked to act as an audience and are given the task of listening for why and how Galileo improved the telescope. They record this information in a KWL graphic organizer.

    Please select one rating (1-6) for this scenario and provide a brief explanation for why you rated the scenario the way you did:

Part Two (Demographic Questions)

1. What grade(s) do you currently teach? (Select all that apply)

   a. 6th grade

b. 7th grade

c. 8th grade

d. Other: (Please Specify) ___________

2. What subjects do you currently teach? (Select all that apply)

a. Science (6th grade)

b. Integrated Science and Earth Systems (7th & 8th grade)

c. Language Arts

d. Mathematics

e. Social Studies

f. Special Education

g. Computers/Technology

h. Music/Art

i. PE

j. Other: (Please Specify) ________________

3. How many years of teaching experience do you have?

a. 0-2

b. 3-5

c. 6-10

d. 11-15

e. 16-20

f. 21-25

g. 26-30

h. 30+

4. How many years has your teaching experience included science?
    a. 0-2
    b. 3-5
    c. 6-10
    d. 11-15
    e. 16-20
    f. 21-25
    g. 26-30
    h. 30+
5. What is your gender?
    a. Male
    b. Female
6. Did you receive your teacher preparation in an elementary education program or a secondary education program? (Select all that apply)
    a. Elementary Education Program
    b. Secondary Education Program
    c. Other: (Please Specify) _______________
7. Have you obtained any endorsements or graduate degrees?
    a. No
    b. Yes: Please specify ____________________

APPENDIX B

Background and Rationale Regarding the Instructional Scenarios

Background Information:

All of the scenarios are based on correct science content, which is selected from the science standards of the state where the research will be conducted (Utah State Office of Education, 2010). This state has not adopted the *Next Generation Science Standards* (NGSS Lead States, 2013) at this time. The standards that are utilized represent sixth grade content knowledge, as this is what the elementary teachers in the state are expected to be familiar with. Additionally, the concepts in these scenarios are content knowledge secondary science teachers are expected to be able to teach in the state in grades 7-8 (Utah State Office of Education, 2010).

The scenarios focus on the degree to which teachers are attending to the science literacy during science instruction as demonstrated through the use of the eight *Practices for K-12 Science* found in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) and the *College and Career Readiness Anchor Standards for Reading and Writing* found in the *ELA CCSS* (NGA & CCSSO, 2010). These documents provide the criteria for rating the science literacy in which students are engaged during instruction.

The specific criteria from the *Practices for K-12 Science Classrooms* used in this document are found in Box 3.1 and include:

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

(NRC, 2012, p. 42)

The specific *Anchor Standards for Reading and Writing* are not written in this document because of their length, but can be found in the complete *ELA CCSS* document (NGA & CCSSO, 2010).

Scenarios and Explanations of Rating:

A. Students independently read a section in a science textbook that describes how force is used to hold celestial objects in orbit around larger objects of greater mass in the solar system. Based on the information in the textbook, each student is asked to create a Haiku or Cinquain poem that describes the role of gravity on the orbits of the Earth and the moon in our solar system. Because the students have been learning about the Impressionist style and the works of the artists Monet and Renoir during art instruction, the students are also asked to illustrate their poem using watercolors.

This scenario is rated as a 1-2. As in each of the scenarios, the science is correct. However, the students in this situation are not using science literacy in authentic ways. According to the *Practices*, they are not analyzing and interpreting data or information. Instead they are merely reading information. The explanation students are constructing does not communicate information in the formal way scientists write (e.g., journals, books, websites) or informal way scientists write (e.g., email, discussion, blogs, notes). Additionally, the *Writing Anchor Standards* call for students to "produce clear and coherent writing in which the development, organization, and style are appropriate to the task, purpose, and audience" (NGA & CCSSO, 2010, p. 41). Writing an illustrated poem is not an authentic task completed by scientists. Therefore, this scenario is an example of not authentic science literacy.

B. The teacher asks the question, "How do the individual organelles in a Euglena (protist) contribute to the function of the whole organism?" Students observe a video of euglena under an electron microscope. They use a computer application to draw a model of a Euglena, label the organelles, and note the organelles' functions within the whole organism. In pairs, students compare their models and note discrepancies. The pairs then compare their models to a model of a Euglena found in a science textbook, revise organelle functions where appropriate, and write an explanation of how the individual organelles contribute to the function of the whole organism.

This scenario is rated as a 5-6. The students are using science literacy in authentic ways during instruction. According to the *Practices*, students are answering a question that explores the natural world and "attempts to extend or refine a model" (NRC, 2012, p. 54). Students are also developing and revising these models, carrying out an investigation, analyzing and interpreting data, constructing explanations, and evaluating and communicating information. Additionally, students are using many of the *Reading Anchor Standards.* Students are "reading closely to determine what the text says explicitly and…making logical inferences from it" (NGA & CCSSO, 2010, p. 35). The students are comparing two texts by analyzing how their text is similar to another student's model and the science textbook's model. Also, students are using many of the *Writing Anchor Standards* including: writing clear explanations that are appropriate for the audience (model and explanation), revising text, using technology to produce text, collaborating with others, investigating a research question, and collecting information from relevant sources. Therefore, this scenario is an example of authentic science literacy.

C. Each student in a class is given six lists of celestial objects found in the solar system that are ordered according to size. Some lists are accurate and others are not. Each student determines one that is correct and makes a claim as to why the objects are accurately classified. Students are placed into groups of five. Within the group they discuss their claims, select one to research, and use technology to access online resources to prove or disprove their group's claim. After researching, students write an argument agreeing or disagreeing with their original claim based on the evidence they found.

This scenario is rated as a 3-4. Students are using many of the *Practices:* planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, engaging in argument from evidence, and obtaining and communicating information. The main issue with this scenario is how the instruction is constructed. Students are originally asked to determine the accuracy of a list and make a claim without evidence. Additionally, the scenario does not represent a natural situation for scientists to engage in argument. According to the *Practices,* students should use argument as "an opportunity to use their scientific knowledge in justifying an explanation and in identifying the weaknesses in others' arguments…also to build their own knowledge and understanding" (NRC, 2012, p. 73). This situation is contrived and not a natural use of argument and so falls short of true argumentation.

In the *Writing Anchor Standards,* students are using multiple sources including technology to research the claims. However, students are not analyzing the credibility of their sources or writing for an authentic science reason. Therefore, this scenario is an example of partially authentic science literacy.

D. Students are asked the question, "What do living organisms need to survive?" In groups of four, students find and use multiple resources to research an answer to the question. As a group, they write a claim based on information from credible sources of science text. Then, they design an experiment to test their claim, conduct the experiment, compile their findings and display the information in a table and/or graph, and write an argument based on their claim. The argument contains conclusions based on evidence found as a result of their experiment and supported by credible sources.

This scenario is rated as a 5-6. Students are using many of the *Practices:* asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, engaging in argument from evidence, and obtaining, evaluating, and communicating information. The scenario does represent a natural situation for scientists to engage in argument because students are "constructing a scientific argument showing how data support a claim…and using reasoning and evidence" (NRC, 2012, p. 72). According to the *Reading and Writing Anchor Standards,* students are conducting a research project, selecting valid evidence from multiple sources, "citing specific textual evidence when writing…to support conclusions drawn from the text" (NGA & CCSSO, 2010, p. 41), writing arguments using credible evidence, and producing writing for a specific purpose. Therefore, this scenario is an example of authentic science literacy.

E. In the classroom, students observe producer and consumer microorganisms that are commonly found in pond water under a microscope (e.g., Paramecium, Amoeba, Euglena, Algae). After completing the observation, students draw examples of the microorganisms. Then, as a class they read a science text that describes the characteristics of producer and consumer microorganisms. While they read, students record information into a concept web graphic organizer because they are studying text structures as a way to improve comprehension. Finally, each student writes a summary of the text utilizing the information in the graphic organizer while also including details from the microorganism observation.

This scenario is rated as a 3-4. The students are using science literacy to a minimal degree in authentic ways. According to the *Practices*, they are communicating information by drawing and writing about their observations. However, the purpose for observing is generic because students lack a focus question/reason to inform their observations and to help them develop a model or explanation. Students are reading text (the visual of the microorganisms in the microscope and the written text) and are writing text to accurately describe information according to the *Reading and Writing Anchor Standards.* However, students are using the standards in a general, content area literacy way that lacks a more exact focus for utilizing science literacy. Therefore, this scenario is an example of partially authentic science literacy.

F. The students are taught that a variety of instruments are used to investigate the moon and planets in the solar system. Some students in the class are assigned a part to read in a reader's theater presentation that discusses Galileo Galilei's life as a scientist, making sure they read with appropriate rate and expression. The rest of the students in the class are asked to act as an audience and are given the task of listening for why and how Galileo improved the telescope. They record this information in a KWL graphic organizer.

This scenario is rated as a 1-2. While the students in this scenario are asked to read or listen (depending upon their assigned role), which are clearly literacy tasks, they are not using science literacy in authentic ways. Those listening are asked simply to recall information. They are not using any of the eight science *Practices* or any of the *Reading and Writing Anchor Standards.* Therefore, this scenario is an example of not authentic science literacy.

APPENDIX C

Implied Consent Form-Survey

Consent to be a Research Participant

You are invited to participate in a research study conducted by Leigh Smith, Kendra Hall-Kenyon, and Melissa Mendenhall from the Department of Teacher Education at Brigham Young University. We are interested in learning about teachers' perceptions of the relationship between science and literacy. You are being asked to participate because you teach in grades 6-8 in a school district that is a member of the BYU-Public School Partnership.

Your participation in this study will require the completion of a six-question survey. It should take approximately 15 minutes of your time. This survey involves minimal risk to you. However, your answers may benefit education by helping increase knowledge about current trends in science instruction.

If you choose to participate, your response will be assigned a number so that the researchers will not know your identity and you will not be identified in any future publication of the results of this study. All raw data will be stored on a password-protected computer in a locked office to keep it secure.

You do not have to be in this study if you do not want to be. You do not have to answer any question that you do not want to answer for any reason. We will be happy to answer any questions you have about this study. If you have further questions about this project, or if you have a research-related problem you may contact Leigh Smith at leigh_smith@byu.edu, Kendra Hall-Kenyon at kendra_hall@byu.edu, or Melissa Mendenhall at mmendenhall@alpinedistrict.org.

If you have any questions about your rights as a research participant you may contact the Institutional Review Board (IRB) Administrator at A-285 ASB, Brigham Young University, Provo, UT 84602; irb@byu.edu; (801) 422-1461. The IRB is a group of people who review research studies to protect the rights and welfare of research participants.

The completion of this survey implies your consent to participate. If you choose to participate, please complete the survey through the link provided and return it within two weeks of receiving this email. We sincerely thank you for your willingness to participate!

APPENDIX D

Follow up to Questionnaire Recruitment Email

If you have already responded to this Questionnaire Survey, we offer our sincere thanks!

Consent to be a Research Participant

You are invited to participate in a research study conducted by Leigh Smith, Kendra Hall-Kenyon, and Melissa Mendenhall from the Department of Teacher Education at Brigham Young University. We are interested in learning about teachers' perceptions of the relationship between science and literacy. You are being asked to participate because you teach in grades 6-8 in a school district that is a member of the BYU-Public School Partnership.

Your participation in this study will require the completion of a six-question survey. It should take approximately 15 minutes of your time. This survey involves minimal risk to you. However, your answers may benefit education by helping increase knowledge about current trends in science instruction.

If you choose to participate, your response will be assigned a number so that the researchers will not know your identity and you will not be identified in any future publication of the results of this study. All raw data will be stored on a password-protected computer in a locked office to keep it secure.

You do not have to be in this study if you do not want to be. You do not have to answer any question that you do not want to answer for any reason. We will be happy to answer any questions you have about this study. If you have further questions about this project, or if you have a research-related problem you may contact Leigh Smith at leigh_smith@byu.edu, Kendra Hall-Kenyon at kendra_hall@byu.edu, or Melissa Mendenhall at mmendenhall@alpinedistrict.org.

If you have any questions about your rights as a research participant you may contact the Institutional Review Board (IRB) Administrator at A-285 ASB, Brigham Young University, Provo, UT 84602; irb@byu.edu; (801) 422-1461. The IRB is a group of people who review research studies to protect the rights and welfare of research participants.

The completion of this survey implies your consent to participate. If you choose to participate, please complete the survey through the link provided and return it within two weeks of receiving this email. We sincerely thank you for your willingness to participate!

APPENDIX E

Codebook

It should be noted that participant responses often included words or phrases that represented ideas that fell into multiple emergent coding categories for each survey question. As a result, a participant's response could contain up to the total number of coding categories identified for each question. For example, questionnaire item #1 (What do you think of as literacy?) resulted in six emergent coding categories. It is possible that a participant's response could have included ideas that represented each of the six coding categories. Additionally, it is important to note that when a response was unclear or absent, it was placed in the No response/Unclear coding category. To clarify the reason why a response was coded in a specific category, italics are included in the portion of the representative participant response that was used to determine the coding category.

Survey Question #1 (What do you think of as literacy?)

Coding Category	**Description**	**Representative Participant Responses**
Reading and Writing	Traditional definition of literacy (e.g., read, read and write, written text, language, grammar, comprehension, phonics and phonemic awareness, vocabulary, fluency)	Anything involving *reading and writing*. Literacy is being able to *read and comprehend what is read*. *Reading, writing, grammar. Phonics. Phonemic awareness. Fluency, comprehension, vocabulary*.
Communication	A way to share ideas	Reading and write in a way that *communicates clearly to others*. *Communicating information*. *Communicate one's language*
Science Literacy	A way of knowing and communicating within the discipline of science	Literacy for science is *understanding how information, data and evidence is gained to make claims*.

	(e.g., multiple modes such as: symbols, graphs, charts; disciplinary literacy)	Literacy is *being able to discuss, understand and communicate with ease, comfort and knowledge in a specific subject*. Being *able to understand written text or mathematical data (tables, charts, or graphs)*. *Being well versed in a discipline*.
Speaking and Listening	Recently recognized additions to the traditional definition of literacy (e.g., speak, listening and speaking, verbal)	*Speaking, listening*. *Speak* fluently in a language. *Verbal language*.
Tool to Access World	Being able to access information for personal use	Basically (sic) literacy is *being able to take in the world around you and use skills to better understand it*. I see literacy as the ability to read and write in *all areas of life*. A tool of *attaining information to be used in other areas and tasks*.
No Response/Unclear		

Survey Question #2 (What do you consider to be text?)

Coding Category	**Description**	**Representative Participant Responses**
Read and Written	Either read or printed (e.g., involves language, read, words, written, published/printed)	Anything that has *words to be read* for any reason. *Written word* (not pictures or graphs). *Published or written material*.
Multiple Modes	Different ways to represent and present meaning (e.g., visual representation, variety of genres such as: articles, newspapers, journals)	*Any symbol (letters, numbers, canyons, data, graphs, rock crystals, facial expressions, colors)* *Any print. Newspapers, TV, books, posters*, etc. *Books, magazines, newspapers, manuals, recipe books. stuff online, texting on phone, signs on the street*. *Pictures or diagrams*.
Conveys Meaning	Purveys understanding	Any form of *media/communication/symbols through which we can communicate*. Words, graphs, or pictures that *convey meaning*. Text can be anything *used to communicate*.
No Response/Unclear		

Survey Question #3 (What types of text do you think of as being used in science?)

Coding Category	**Description**	**Representative Participant Responses**
Informational Texts	Nonfiction texts (e.g., variety of genres, newspapers, magazines, reports, documents, articles, technology, online sources, multimedia presentations, video, media, journals, research lab work, descriptions, notes, science notebooks, experiments, observations, reading the equipment, models, textbooks)	I think of books, *articles, journals, websites, charts, and graphs* as being texts used in science. *Data tables, graphs*, concept maps, *diagrams* Slide shows, *lab directions,* maybe some *articles*. *Journals, notes, research papers,* books. *Lab reports, Scientific Journals, Textbooks, Current Event Articles, Experiments, Graphs, Data Tables*.
Visual Representations	Ways to represent meaning (e.g., symbols, multiple modes, data, formulas, tables, graphs, diagrams, charts, pictures, captions, concept maps)	*Diagrams, charts*. *Pictures, words, diagrams, models, videos, posters, graphs*.
Written	Texts must be written	*Written text*, illustrations, diagrams, models, etc. I use a lot of *written text* in Science, like handouts and booklets. Any *written* information.
Narrative Texts	Texts written using fictional ideas	Expository text to inform, *historical fiction* (on occasion) to emphasize and make real, persuasive articles, etc. Usually nonfictional (sic), informational texts would be used in science, but *fictional texts* can also be used, as well as pictures, and graphs, etc. Magazine (sic), expository, *narratives*, online articles, journals.

Quiz/Worksheet	Instructions or assessments created to guide or assess instruction	Bellringers, *tests, quizzes*. Written words used in questions on a *test*. Paragraphs on *worksheets*.
No Response/Unclear		

Survey Question #4 (What does science literacy mean to you?)

Coding Category	**Description**	**Representative Participant Responses**
Integration of Science and Literacy	Science and literacy instruction happen simultaneously	The *integration of literacy concepts with science content*. *Teaching science through literacy*. Science literacy means that you have attempted to *cross the two curriculums together*. Killing two birds with one stone.
General Literacy	Skills associated with literacy (e.g., read and write, vocabulary, comprehend, text, speak and listen)	The ability to *read and understand written materials* at a normal level for students of a similar age. *Reading* a passage and answering questions about it. Being able to learn from *reading text*.
Science Literacy	A way of knowing and communicating within the discipline of science (e.g., uses science practices, argument in science, obtain information, understand nature of science, understand science concepts, understand how to research, understand math, contains knowledge, a way to understand the world, understand data use, evaluate information, how to find answers, understand science text)	Science literacy means that students are *able to* (sic) *use different practices and scientific methods of thinking to investigate a question about the world around them*. Being *able to understand how information/data is gathered and used to help with understanding the natural world*. Science literacy is *understanding and developing skills that scientists use every day*. *Content knowledge is certainly a part of this*, *but it is more about learning to become someone who questions things, explores questions, and presents conclusions*.
No Response/Unclear		

Survey Question #5 (Scenario #1)

Coding Category	**Description**	**Representative Participant Responses**
Integrates Art	Art is used to facilitate science instruction and/or art and science are being taught at the same time (e.g., promotes creativity and understanding)	*Integrating skills from other academic areas* but relying on each others (sic) understanding of the concept. *Art skills used to support the science concept*. I think the shows an excellent *blending of the curriculums*.
Poor Instructional Strategies	Instructional strategies generally thought to be ineffectively at facilitating student understanding (e.g., simplistic, vague, no check for accuracy, no differentiated text, no shared reading, no group work, no multiple learning styles, lacks scaffolding, no discussion, not effective instruction, uses textbook, low depth of knowledge, not hands-on)	I feel that *if students are simply reading a text, they are not learning much from it*. They learn so much more from discussion and hands on! I *would have made sure of the students understanding of the article before moving forward* with poem. The students are *reading and writing, but there is no verbal component*. They do not have to speak or listen. There is also *no opportunity to clarify their understanding* before producing a final product, so the student may not be "literate" in what they read or wrote. They may not understand it.
Not Science Literacy	Lacks ways of knowing and communicating authentic to the discipline of science (e.g., not science literacy, lacks science practices, limited science understanding, not real world, no investigation, diverts student focus from science)	It *lacks any science practice*. They do gain some science content knowledge however it is a low level task and the literacy component is *not authentic to what actual scientists would do*. *They weren't using science literacy*. They were reading and writing poems. Maybe catching a little bit of science along the way. That lesson seems more like poetry literacy.
Good Instructional Strategies	Instructional strategies generally thought to	*Integrated learning is best* for students. The more multiple

	effectively facilitate student understanding (e.g., deep depth of knowledge, uses multiple learning styles, demonstrates understanding, multiple assessment forms, gaining and demonstrating understanding)	intelligences you can reach the better the comprehension and retention. This task requires students to formulate information in their mind and then *communicate their understanding via a new mode of learning*. They are able to (sic) explain the concept in a form other than the medium it was delivered in. It *requires understanding* to do so.
Integration Does Not Work Here	Art instruction does not improve science instruction (e.g., no skill building in content other than science, diverts student focus from science)	This teaches the principle but the *emphasis on art detracts from the focus*. *If we are focusing on the scientific part writing a poem is not doing this*. That would be focusing on the literacy part but not specifically the role of gravity and orbits. *It is teaching their understanding of vocabulary and art, but not science*.
General Literacy	Skills associated with literacy (e.g., read and write, vocabulary, comprehend, text, speak and listen)	Its good because it incorporates *reading and writing* together. I think this covers a lot of curriculum as it gives the students the ability to *use literacy skills* in science. I believe that the science reading is strong, but I would probably have them *use a different form of poetry that requires more than syllables*.
Science Literacy	A way of knowing and communicating within the discipline of science (e.g., uses science practices, argument in science, obtain information, understand nature of science, understand science concepts, understand how to research, understand math, contains knowledge, a way to	I think that is a perfectly fine way of *using scientific literacy*.

	understand the world, understand data use, evaluate information, how to find answers, understand science text, includes research, multimodal, includes observation, authentic learning experiences, uses technology, disciplinary literacy)	
No Response/Unclear		

Survey Question #6 (Scenario #2)

Coding Category	**Description**	**Representative Participant Responses**
Good Instructional Strategies	Instructional strategies generally thought to effectively facilitate student understanding (e.g., students communicate understanding, student-centered instruction, differentiated instruction, engaging, high depth of knowledge)	*Direct and clear* and leads to student being able to *communicate what he learned*. Good because they are using *DOK [Depth of Knowledge] skills* and they are probably totally *engaged*. Individual *student centered* (sic) information gathering as expressed by a functunal (sic) expression.
Science literacy	A way of knowing and communicating within the discipline of science (e.g., uses science practices, argument in science, obtain information, understand nature of science, understand science concepts, understand how to research, understand math, contains knowledge, a way to understand the world, understand data use, evaluate information, how to find answers, understand science text, includes research, multimodal, includes observation, authentic learning experiences, uses technology, disciplinary literacy)	*Using models* and *comparing* examples and evidences is a good science skill. Students are *observing, researching,* drawing, and summarizing their learning. Everything thing that is being done functions to understand, *use the information, explain and justify the information and reason with it*.
General Literacy	Skills associated with literacy (e.g., read and write, vocabulary, comprehend, text, speak and listen)	They seemed to do a lot with it and they themselves are *writing* about it but I dont (sic) think they are reading anything about it *Incorporates several forms of literature*. The activities *reinforce the vocabulary through visual aids practice* and follow-up.

		They *interpreted text*, made models, *checked for understanding* and *wrote* an explanation.
Poor instructional strategies	Instructional strategies thought to be ineffective at facilitating student understanding (e.g., promotes limited understanding, uses textbooks, low depth of knowledge, no debrief, not student-centered, lacks scaffolding, poor language arts instruction)	They understood the *local concept* well, but *not how it connects to larger concepts*. *Doesn't seem to be too deep of a DOK [Depth of Knowledge]*. Replicating that information, but not really applying it. *A little flat in application*, the drawing and writing *don't evoke an opportunity to make a memorable experience where they would actually remember and retain*.
Not Science Literacy	Lacks ways of knowing and communicating authentic to the discipline of science (e.g., not science literacy, lacks science practices, limited science understanding, not real world, no investigation, diverts student focus from science)	While the students interacted with technology to draw and label, their primary *experience was not with the investigation* rather with the explanation. This is *rote information* on the structure of the Euglena. *Students need to see the Euglena moving in it's* (sic) *environment and reacting to stimuly* (sic) *to understand the various functions of the organells* (sic).
Integrates Art	Art is used to facilitate science instruction and/or art and science are being taught at the same time (e.g., promotes creativity and understanding)	*Integrating skills from other academic areas* but relying on each others (sic) understanding of the concept. *Art skills used to support the science concept*. I think the shows an excellent *blending of the curriculums*.
Integration Does Not Work	Literacy skills are not used during instruction	This is *very little reading and writing* in this activity. *Lacks the cross curricular approach*.

		Nice lesson put *not much with literacy*.
No Response/Unclear		

Survey Question #7 (Scenario #3)

Coding Category	**Description**	**Representative Participant Responses**
Science Literacy	A way of knowing and communicating within the discipline of science (e.g., uses science practices, argument in science, obtain information, understand nature of science, understand science concepts, understand how to research, understand math, contains knowledge, a way to understand the world, understand data use, evaluate information, how to find answers, understand science text, includes research, multimodal, includes observation, authentic learning experiences, uses technology, disciplinary literacy)	Students *doing research and defending their claim in a written argument*. There is *analyzing, justifying, and communicating*. They are asked to *use evidence to justify their explanation*. Another *critical thinking process using reliable resources*. *Argumentative writing claims* and technology.
Good Instructional Strategies	Instructional strategies generally thought to effectively facilitate student understanding (e.g., students communicate understanding, student-centered instruction, differentiated instruction, collaboration, engaging, high depth of knowledge)	The *objective is clear* and I like *collaborative aspect* and again must communicate affectively (sic). This is a *good introduction activity where they can explore*. The students are *encouraged to work together* and it sort of teaches the scientific method (hypothesis, research, analyzing, concluding). I think it is a good way to assess what they know, giving them the chance to research and argue whether they were right or not. I also like the *cooperative learning*.
General Literacy	Skills associated with literacy (e.g., read and write, vocabulary, comprehend, text, speak and listen)	Great *writing* activity. The students *read, write, listen, and speak*. They have opportunities to revise their ideas and learn correct information.

		Strong connection to literacy practices with *writing researching comparing and producing*.
Poor Instructional Strategies	Instructional strategies generally thought to be ineffective at facilitating student understanding (e.g., promotes limited understanding, uses textbooks, low depth of knowledge, no debrief, not student-centered, lacks scaffolding, poor language arts instruction)	Again, *teacher facilitation for a launch would be paramount as well as a teacher-facilitated debriefing afterwords* (sic). Once again, I am a hands on (sic) type of person. This all sounded good but *create something and explain its purpose in the study of it*. The *size of the group may limit the interactions* of the kids with the material and the discussion. *Low level comparison*.
Integrates Art	Art is used to facilitate science instruction and/or art and science are being taught at the same time (e.g., cross curricular)	*Integrated use of several areas*. This is a *good blending of the curriculums*. I like the way that *argumentative writing is incorporated into the science curriculum*. They are learning much about space while at the same time learning how to find evidence and make and support a claim.
Not Science Literacy	Lacks ways of knowing and communicating authentic to the discipline of science (e.g., not science literacy, lacks science practices, limited science understanding, not real world, no investigation, diverts student focus from science)	*Lacks real scaling* and seems more like a recall and report activity. This is good at comparing, but I *would say it is more of a language arts lesson than a science lesson*. Great activity and practice for literacy but *not great for teaching how to read a science text*.
No Response/Unclear		

Survey Question #8 (Scenario #4)

Coding Category	**Description**	**Representative Participant Responses**
Science Literacy	A way of knowing and communicating within the discipline of science (e.g., uses science practices, argument in science, obtain information, understand nature of science, understand science concepts, understand how to research, understand math, contains knowledge, a way to understand the world, understand data use, evaluate information, how to find answers, understand science text, includes research, multimodal, includes observation, authentic learning experiences, uses technology, disciplinary literacy)	*Writing is based on evidence. It includes research needed to gather knowledge.* *Students gather information, plan and carry out an investigation, then communicate their findings*. There are *many scientific practices* here. Students are *researching before making a claim*, so the chances their information is correct will be highly probable. They then are *putting their claim to the test and basing the results off of (sic) evidence*. Wow, their using the scientific process and following it all the way through! It sounds like there is deep, and logical thinking going on along with *learning the mechanics of research and communicating that research*.
Good Instructional Strategies	Instructional strategies thought to effectively facilitate student understanding (e.g., students communicate understanding, student-centered instruction, differentiated instruction, collaboration, engaging, high depth of knowledge)	Is *well thought out*. This is a *high level* (sic) *task*. *Student centered* (sic) investigative science given a verity (sic) of resources to formulate a workable, informed (sic) hypothesis. This is good because students can *work together in small groups*. They are able to (sic) *show their understanding in multiple ways*.
General Literacy	Skills associated with literacy (e.g., read and write, vocabulary, comprehend, text, speak and listen)	*Using all the tools of literacy*. Again (sic) *multiple sources with a good tool to see understanding*.

		They *work orally, then read, then write* to solidify their understanding.
Integrates Art	Art is used to facilitate science instruction and/or art and science are being taught at the same time (e.g., cross curricular)	*Science being supported by the other content areas of school*. Cross curricular. Almost all of the *literacy assessments in this scenario involve science* material.
Too Hard/Takes too Long	Instruction is unreasonably rigorous or time consuming	A little *difficult for them to conduct an investigation without necessary supplies*. Sometimes you have supplies but a lot of the time you don't. *Sounds perfect ... If you have 5 hours of classroom time*. How long is the time span for their investigation, this sound very appropriate but true science research projects take many days and working in groups of four for long periods of *time is difficult with the huge number of days many kids are absent*. I like this but I wouldn't have the resources available. *Our time is also limited* in an elementary setting.
Poor Instructional Strategies	Instructional strategies thought to be ineffective at facilitating student understanding (e.g., promotes limited understanding, uses textbooks, low depth of knowledge, no debrief, not student-centered, lacks scaffolding, poor language arts instruction)	*No debrief or discussion* with a teacher happens here. I think *the question* "What do living organisms need to survive" *is weak* and *doesn't really create higher thinking*. *Give more possible ways to research material*.
Diverts Focus from Science	Science understanding and skills are not emphasized during instruction	Again, I feel *this is more of demonstrating literacy in reading*, but not collecting data and comparing it to determine their own findings.

		Good, but again, for the lower student a leader usually does all of the work or they *spend time trying to defend their idea and not on the topic*.
No Response/Unclear		

Survey Question #9 (Scenario #5)

Coding Category	**Description**	**Representative Participant Responses**
General Literacy	Skills associated with literacy (e.g., read and write, vocabulary, comprehend, text, speak and listen)	*Using organization skills graphic organizers and writing about their findings*. The *graphic organizer* helped them clearly communicate the content. I believe students should learn at least a little before observing the microorganisms. *If they read first, they will know more about what they are seeing* in the microscope. *Writing a summary based on a graphic organizer* can be a good way to help remember the information they learned, though.
Science Literacy	A way of knowing and communicating within the discipline of science (e.g., uses science practices, argument in science, obtain information, understand nature of science, understand science concepts, understand how to research, understand math, contains knowledge, a way to understand the world, understand data use, evaluate information, how to find answers, understand science text, includes research, multimodal, includes observation, authentic learning experiences, uses technology, disciplinary literacy)	*Observation was used, then they found information through research and then produced a paper*. It is *sythesizing information from multiple sources and writing findings* Students are *observing and recording their observations*.
Good Instructional Strategies	Instructional strategies thought to effectively facilitate student understanding (e.g., students communicate understanding, student-centered instruction,	*Appeals to many different learning styles* and follows much of the scientific method. The *students are working together*, with instruction from the teacher.

	differentiated instruction, collaboration, engaging, high depth of knowledge)	It is *sythesizing* (sic) *information from multiple sources* and writing findings. *Shows individual learning* as well as *interactive learning with peers*. *Higher DOK [Depth of Knowledge]*. Involved. Lots of thinking.
Integrates Art	Art is used to facilitate science instruction and/or art and science are being taught at the same time (e.g., cross curricular)	*Integrating reading and writing is a great way to teach science*. I like the hands-on personal observations and the *integration of literacy to support their scientific observations*. *Good integration* and I like that the students recognize that the structure of the text will help them get information from it.
Not Science Literacy	Lacks ways of knowing and communicating authentic to the discipline of science (e.g., not science literacy, lacks science practices, limited science understanding, not real world, no investigation, diverts student focus from science)	I feel its (sic) *a bit heavy focus on ELA not science*. They made observation, but *didn't talk about the structure and function of what they were seeing. Then they didn't communicate their findings*. *This is a good writing lesson, but not as good of a science lesson*. *No essential question* before the scientific process.
Poor Instructional Strategies	Instructional strategies thought to be ineffective at facilitating student understanding (e.g., promotes limited understanding, uses textbooks, low depth of knowledge, no debrief, not student-centered, lacks scaffolding, poor language arts instruction)	The *thinking is not very deep*. *No debrief or discussion*. There is a *little "hands on" and "discovery"* with the microscopes. The complete the reading as a class, but it doesn't say anything about discussing as a class, with a peer group, or anything like that. The graphic organizer is good and the summary is a way of assessing

		student knowledge. Just seems like the sandwich needs more meat. More discovery, more hands on, etc.
Limited General Literacy	Skills associated with literacy are underutilized during instruction	Like that its real but *they could do more with it than write a summary*. *Organizing info but not transferreing* (sic) *to another form*. *While the students are reading, writing, and listening, there isn't much opportunity to speak*. Reading out loud with the class doesn't really count as speaking, because the students are not speaking about their original thoughts.
No Response/Unclear		

Survey Question #10 (Scenario #6)

Coding Category	**Description**	**Representative Participant Responses**
Poor Instructional Strategies	Instructional strategies thought to be ineffective at facilitating student understanding (e.g., promotes limited understanding, uses textbooks, low depth of knowledge, no debrief, not student-centered, lacks scaffolding, poor language arts instruction)	They'll (sic) be *a number of students that won't be engaged* in taking KWL notes while listening as the audience. *NOT very engaging* for all students. I think that *it would be time consuming*. *Little depth of understanding*.
Not Science Literacy	Lacks ways of knowing and communicating authentic to the discipline of science (e.g., not science literacy, lacks science practices, limited science understanding, not real world, no investigation, diverts student focus from science)	*Great reading activity but where is the science*. *Readers theater is not an authentic way scientists are literate.* *There is no record keeping and students arent* (sic) *actually experiencing what is necessary to gather knowledge*. *There is no science happening here. No cross cutting* (sic*)concepts or practices were introduced, used, or talked about*.
General Literacy	Skills traditionally associated with literacy (e.g., read and write, vocabulary, comprehend, text, speak and listen)	*Listening and retell skills.* The *KWL organizer provides a means to process and categorize* (sic) *info*. For the students *listening*, information is learned and recorded, for the students reading *they are practicing reading skills*.
Good Instructional Strategies	Instructional strategies thought to effectively facilitate student understanding (e.g., students communicate understanding, student-centered instruction, differentiated instruction,	Good use of *graphic organizer* and appeals to some students (sic)desire for attention in an affective (sic) way. Fun *interactive literacy practice* with reader's theater.

	collaboration, engaging, high depth of knowledge)	The kids love reader's theaters and this a *great way to engage* them.
Limited General Literacy	Skills associated with literacy are underutilized during instruction	*More writing needed*. A readers (sic) theater is still reading but the *whole class is not involved and the reading is only from once source and minimal*. *Needs multiple resources*, not a very good way to evaluate student understanding.
No Response/Unclear		