A MULTIPLE CASE STUDY: DISCIPLINARY LITERACY INSTRUCTION IN MIDDLE LEVEL SCIENCE CLASSROOMS

by

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Dedication

Dedicated to my supportive family, especially Johanna, Ella, and Blake, who have lived this process with me and always encouraged me to continue to move forward.
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Abstract

The National Center for Education Statistics (NCES, 2017) reported that literacy scores have not significantly improved in over 20 years. These scores have prompted investigations of instruction for improving literacy instruction, such as disciplinary literacy (DL), but research supporting DL implementation is limited (Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). The purpose of this qualitative case study was to explore the DL instruction implemented in middle level science classrooms in an urban middle school in the United States. The qualitative research paradigm was selected to explore science teacher implementation of DL. Drawing from Shulman’s (1986, 1987) theory of pedagogical content knowledge (PCK), educator practices were investigated using multiple qualitative case study methodology. Shulman’s (1986, 1987) theoretical constructs of content knowledge, pedagogical knowledge, and PCK developed to explain teacher decision-making and instruction were used in this study to explore educator understanding and actions related to DL. Three participants, two veteran teachers and one novice teacher, represented three cases inclusive of science instruction in Grades 6-8. Major findings include participants’ expanded definitions of text for literacy, impacts of professional development on DL PCK, the use of both content area and DL, integration of DL with science practices, and the simultaneous development of science and DL PCK. Implications of this study include the need for policies for developing PCK of DL and transfer of learning into teacher practice to improve science and literacy instruction. Further research is necessary to understand the impacts of DL instruction on student achievement.
Chapter 1: Introduction

The National Center for Education Statistics (NCES, 2017) reported a lack in significant growth of reading scores on national standardized assessments that have given rise to reform documents that call new attention to the development of disciplinary literacy in the science classroom (Hannant & Jetnikoff, 2015; National Governor’s Association Center for Best Practices [NGACBP] & Council of Chief State School Officers [CCSSO], 2010; Next Generation Science Standards [NGSS] Lead States, 2013). Researchers, such as Moje (2008) and Shanahan and Shanahan (2008), responded to the need to improve literacy achievement and the calls for reform by advocating an approach termed disciplinary literacy that focuses on literacy instruction that is consistent with literacy use by disciplinary experts. Limited research on implementation of disciplinary literacy instruction in the science classroom has been completed, resulting in a gap in research (Fang & Coatoam, 2013). Since much of the work concerning disciplinary literacy instruction has been theoretical or conceptual, a need for understanding implementation of disciplinary literacy instruction is necessary (Fang & Coatoam, 2013; Fisher & Ivey, 2005).

The purpose of this qualitative case study was to explore the disciplinary literacy instruction implemented in science classes. Shulman’s (1986, 1987) theory of PCK framed the study. The theory of PCK was developed by Shulman (1986, 1987) around the constructs of content knowledge, pedagogical knowledge, and interactions between content and pedagogy in PCK. The constructs of PCK provided the lens for the exploration of teacher decision-making and instruction related to disciplinary literacy instruction in science and were applied within the selected qualitative research paradigm to guide the exploration of the instructional approaches used by three participants in an urban middle school in the United States. Multiple qualitative
case study methodology was chosen due to the focus of the study as an exploratory investigation of teacher understanding and practices.

This chapter explores the background and conceptualization of disciplinary literacy as a contemporary problem in education for both educators and researchers. The problem is stated followed by the presentation of the purpose of the current study. An overview of the theoretical framework of Shulman’s (1986, 1987) PCK and methodology of qualitative case study are described. The research questions addressed in the study are presented. Delimitations and limitations of the study are described. The significance of the study in filling gaps in existing research pertaining to the implementation of disciplinary literacy in the science discipline and the potential impacts on teacher practice and educational policy decisions is discussed. Key terms are then defined and followed by an organization of this study as applied to the traditional five-chapter dissertation structure. The chapter concludes with a summary that overviews the key components of the study.

**Background and Contextualization of the Issue**

Persistently low levels of student literacy as measured by national standardized assessments in reading have indicated the need for attention to improving student literacy skills in the United States (Fisher & Ivey, 2005; National Center for Education Statistics [NCES], 2017). The most recent administrations of the National Assessment of Educational Progress (NAEP), for instance, indicated that average reading scores of students in the United States remain at the basic level (NCES, 2017). In the nearly 50 years since Herber (1970) introduced the idea of every content teacher being a teacher of reading, the expected gains in student literacy achievement have not met expected outcomes as measured by national literacy measures (Fisher & Ivey, 2005; Moje, 2008, 2015; NCES, 2017; Shanahan & Shanahan, 2008, 2015). The need
for improvement in literacy instruction has therefore become a renewed focus of classroom instruction (Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015).

The focus on expectations for literacy achievement is one driving factor that influenced the roles of the disciplinary or content teacher with regards to literacy instruction (Fisher & Ivey, 2005; Herber, 1970; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). The evolution of educator roles and changes in instruction paralleled the development and implementation of new standards (Fisher & Ivey, 2005; Zygouris-Coe, 2012). The most recent iterations of literacy instruction in content areas resulted from the Common Core State Standards (CCSS; NGACBP & CCSSO, 2010) in the United States and similar movements throughout the world (Hannant & Jetnikoff, 2015). These new standards moved beyond a singular focus on reading and include reading, writing, and speaking and listening (NGACBP & CCSSO, 2010). The reading, writing, and speaking and listening components of literacy are further supported in science instruction through the learning about and application of science and engineering practices presented in the Next Generation Science Standards (NGSS; NGSS Lead States, 2013).

The National Research Council (NRC, 2012) outlined eight “science and engineering practices” (p. 42) that included skills and behaviors of scientists and engineers that enable them to deepen their conceptual understanding, engage in research, or construct new knowledge. The practices included “asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information” (NRC, 2012, p. 42). The practices used by scientists require the use of communication where students must read, write, and engage in verbal discourse that includes presentation and critique of science ideas and
current thinking of scientists and students. Norris and Phillips (2003) placed the use of literacy in science practices in a domain they term literacy in the “fundamental sense” (p. 224) that includes the use of language, such as through reading and writing, to communicate in science. This form of “fundamental” (Norris & Phillips, 2003, p. 224) literacy was a requisite skill to be applied in the development or construction of content knowledge and understanding termed the “derived sense of literacy” (Norris & Phillips, 2003, p. 233) or knowledge about science that results in bringing together information through analysis and critical thinking. Practices that parallel those used by expert scientists can be taught at appropriate levels and therefore allow students to engage in behaviors that incorporate literacy as a means for constructing scientific knowledge, making sense of prior knowledge and new learning, and communicating knowledge (Berland & Reiser, 2008; Ford, 2008; Klahr & Dunbar, 1988; Norris & Phillips, 2003; NRC, 2012; Schwarz et al., 2009).

Shanahan and Shanahan (2008) described an approach to literacy instruction through authentic uses of literacy as exhibited in the work of expert scientists. Framing instruction of literacy in the practices of scientists can integrate science content knowledge, thematic knowledge that influences content knowledge, and procedural knowledge of science practices presented in the NGSS (Houseal, Gillis, Helmsing, & Hutchison, 2016; NGSS Lead States, 2013). The deliberate use of these practices has the potential to provide more authentic experiences and opportunities for students to construct content knowledge and knowledge of practices that contribute to disciplinary literacy (Ford, 2008; Houseal et al., 2016; Norris & Phillips, 2003). Shanahan and Shanahan (2008) presented approaches to disciplinary literacy instruction that requires authentic approaches in the use of disciplinary literacy and science skills.
The shift in literacy instruction proposed by Moje (2008) and Shanahan and Shanahan (2008) may be viewed as an emphasis of literacy skills and practices used by scientists and science students and moving away from generalized strategy instruction termed content area literacy (Ford, 2008; Klahr & Dunbar, 1988; Norris & Phillips, 2003). Faggella-Luby, Graner, Deshler, and Drew (2012) stated the need for balancing disciplinary literacy instruction with content area literacy instruction to support the use of reading and writing varied texts to construct science knowledge as described by Norris and Phillips (2003). Moving from the balance of instruction described by Faggella-Luby et al. (2012), disciplinary literacy as advocated by Moje (2008) and Shanahan and Shanahan (2008) can create a science learning environment that is relevant and authentic to both content and practice instruction. The use of literacy skills in the science classroom as presented by Moje (2008) and Shanahan and Shanahan (2008) aligns with reforms in science education that engage students in learning as scientists through science practices (Houseal et al., 2016; NGSS Lead States, 2013).

The integration of reading, writing, and speaking and listening skills with science practices relies on educator design and implementation of literacy instruction that provides meaningful student learning opportunities (Fang, 2012; Fang & Coatoam, 2013; Goldman et al., 2016; Houseal et al., 2016). Educators are responsible for understanding the content knowledge as well as the disciplinary “habits of mind” (Fang & Coatoam, 2013, p. 628) that influence what Gillis (2014) termed “discipline appropriate literacy practices” (p. 621). Successful implementations of disciplinary literacy instruction and subsequent opportunities for student learning depend on educator abilities and willingness to bring together strategies for cohesive, authentic learning opportunities (Drew & Thomas, 2018; Fisher & Ivey, 2005). However, a majority of research on literacy instruction focused on individual, general instructional strategies
for reading, writing, and speaking and listening (i.e., content area literacy) without the inclusion of the unique aspects of science disciplinary literacy (Fang & Coatoam, 2013; Houseal et al., 2016; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). Educator knowledge of the content and pedagogy of disciplinary literacy are investigated through the lens of Shulman’s (1986, 1987) theory of PCK as applied to science instruction (Cooper, Loughran, & Berry, 2015; Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2008). Additionally, educator perspectives on disciplinary literacy based on understanding and training are explored to gain insight into the implementation or challenges that prevent disciplinary literacy practices (Cooper et al., 2015; Magnusson et al., 1999; Park & Oliver, 2008).

Researchers presented the potential benefits of disciplinary literacy instruction and an overview of instruction focused on authentic experiences aligned to the practices of scientists, but further research in understanding practices of disciplinary literacy instruction is necessary (Faggella-Luby et al., 2012; Fang & Coatoam, 2013; Fisher & Ivey, 2005; Drew & Thomas, 2018; Houseal et al., 2016; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). Prior research did not investigate the teacher actions that move from conceptual understanding of disciplinary literacy to practical classroom implementation (Fang & Coatoam, 2013). Furthermore, additional research is necessary to explore the balance of literacy approaches to include a balance of content and disciplinary literacy approaches as proposed by Brozo, Moorman, Meyer, and Stewart (2013) and Faggella-Luby et al. (2012). Fang and Coatoam (2013) acknowledged the need for additional research to develop an understanding of practices for implementing disciplinary literacy practices. This study was completed within a context that lacked research evidence for the implementation of disciplinary literacy practices in classrooms (Fang & Coatoam, 2013; Houseal et al., 2016).
Problem Statement

Literacy has been an area of instructional focus for nearly 50 years with origins in Herber’s (1970) articulation of literacy instruction as a responsibility of all teachers. Fisher and Ivey (2005) also presented literacy instruction as important across disciplines and therefore a necessary component of teacher planning and implementation of lessons. Although Herber (1970) advocated all teachers as reading teachers and educational institutions have embraced this approach, disciplinary teachers have not consistently implemented literacy instruction (Fisher & Ivey, 2005). One reason for the inconsistent implementation of literacy was identified in research as a lack of relevance to the discipline (Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). The lack of relevance to the discipline impeded the ability of teachers to create meaningful literacy learning opportunities (Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015).

Even though literacy instruction has been advocated across disciplines, Fisher and Ivey (2005) and Shanahan and Shanahan (2008, 2015) presented a lack of literacy achievement. This lack of achievement is corroborated by national standardized testing measures. Reading scaled scores in the United States since 1992 have ranged between 260 and 265 as reported by the NCES (2017). This range does not represent statistically significant differences in student achievement (NCES, 2017). Additionally, average scores in the last 20 years of NAEP reading assessments have shown that students in the United States remained at the basic level (NCES, 2017). The lack of progress in student achievement demonstrated a need for improved literacy instruction (Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015).

In an effort to initiate the reform of literacy instruction, Shanahan and Shanahan (2008, 2015) proposed the use of instructional approaches that authentically incorporated literacy
instruction and application of literacy skills. Research supported varied approaches to literacy instruction that included disciplinary literacy but did not delineate methods for implementation of disciplinary literacy (Fang & Coatoam, 2013; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). The need for authentic, real-world applications of literacy in the disciplines is neglected by instruction solely focused on generalized strategies (Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). Researchers such as Fisher and Ivey (2005), Moje (2008, 2015), and Shanahan and Shanahan (2008, 2015) called on educators to adjust to disciplinary literacy instruction that effectively allows change in student achievement. Changes in achievement were to be driven by the engagement of students in authentic, social experiences that move beyond isolated strategies and mirror real-world literacy use by disciplinary experts (Moje, 2008, 2015; NRC, 2012; Shanahan & Shanahan, 2008, 2015).

While research exists on best practices related to individual constructs of literacy, disciplinary literacy requires an integration of all constructs, reading, writing, and speaking and listening, into science content and practices instruction (Fang & Schleppegrell, 2010; Fisher, Grant, & Frey, 2009; Guzzetti & Bang, 2011; Michaels, O’Connor, & Resnick, 2008; Moje, 2015; Norris & Phillips, 2003; Silva, Weinburgh, & Smith, 2013; Zmach et al., 2006). When implementing literacy instruction focused on the disciplinary uses within science, pedagogy includes science practices for obtaining and communicating information, investigation, modeling, and discourse (Drew & Thomas, 2018; Houseal et al., 2016; NRC, 2012; NGSS Lead States, 2013). Additional research into educator knowledge about, attitudes toward, and implementation of disciplinary literacy instruction can inform science education practices. Opportunities for student learning can result from instruction based on educator understanding that integrates content standards, science and engineering practices, and literacy skills (Drew &
Thomas, 2018; Faggella-Luby et al., 2012; Moje, 2008; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Shanahan & Shanahan, 2008). The understanding of integration of disciplinary literacy instruction in science requires an investigation of educator actions that provide opportunities for learning science and literacy.

**Purpose Statement**

The purpose of this qualitative case study was to explore the disciplinary literacy instruction implemented in middle level science classrooms in an urban middle school in the United States.

**Overview of Theoretical Framework and Methodology**

Norris and Phillips (2003) argued that educators must bring together practices for constructing knowledge with the factual and conceptual knowledge of science. When considering multiple domains of the science discipline, the investigation of disciplinary literacy instruction in science classrooms should address varied actions of the educator, including actions from planning through implementation and reflection (Shulman, 1987). The theory of PCK was used to support a multiple case study approach in the investigation of disciplinary literacy instruction.

**Theoretical framework.** Teaching and learning has been identified as a complex system requiring interactions of students and teachers with content, processes, and each other (Shulman, 1987). These interactions are guided by decisions made both before and during instruction. The decisions of teachers and interactions of teachers and students, therefore, rely on the teachers’ understanding of the content, the pedagogy, and the needs of the students in the classroom (Shulman, 1986, 1987). By drawing attention to the balance of components required for effective
instruction, Shulman (1986, 1987) identified the intersectionality of various considerations throughout the planning and implementation of opportunities for teaching and learning.

**Historical development.** Historically, teacher preparation, certification, practice, and evaluation have emphasized either content knowledge or pedagogical understanding and skill (Shulman, 1987). Shulman (1983) viewed shifts in approaches to education as the result of behaviors driven by values and fears. Policies may be driven by fears of incompetent teachers and teachers may react out of fear that policies set unattainable expectations (Shulman, 1983). While policymakers and teachers may both react out of sets of fears, the actions are described by Shulman (1983) as directed toward the societal value placed on education. Actions to improve schools or create meaningful change in educational systems rely on bringing together policy, research, and pedagogy (Shulman, 1970, 1974, 1983).

To address what Shulman (1986, 1987) viewed as an overemphasis of pedagogy at the expense of content, Shulman (1986, 1987) proposed a balance of pedagogy and content in forming the instructional approaches of educators. The proposed balance requires a re-emphasis of content in teacher knowledge. Shulman's (1986, 1987) re-emphasis of content knowledge did not preclude the use of varied teaching techniques. Building on Bruner's (1960) educational theory that included "understanding" and "doing" (p. 29) and Dewey's (1904, 1911) idea that moved beyond discrete facts to broader understanding of ideas, Shulman (1989) overviewed the importance of teaching processes that aided in eliciting and constructing student knowledge. Teaching processes should recognize the context in which instruction will occur and thus adapt content and pedagogy to fit the needs of learners in each situation (Shulman, 1970, 1983, 1986).

Effective instruction requires the educator to have a balance of knowing the content and practicing skills or pedagogy that makes content understandable for students. Shulman's (1986)
theory of PCK was applied to explain the overlap of content and pedagogical knowledge. As novice and veteran educators discussed their thought processes of planning and implementing instruction, links between specific content topics and pedagogical strategies for teaching the content were identified by Shulman (1987). Pedagogical content knowledge can be learned and applied through varied approaches, such as apprenticeship or laboratory settings, and can aid educators in establishing effective practices that promote meaningful learning (Shulman, 1986, 1987).

The theory of PCK recognized the importance of context and the overall educational goals or outcomes (Grossman, 1990; Shulman, 1986, 1987). To meet established educational expectations, PCK was constructed on the knowledge of individual educators. Shulman (1986, 1987) stressed that content knowledge is essential for teaching, but content relies on pedagogy for the creation of learning experiences. The theory of PCK is supported by the individual constructs of content knowledge and pedagogical knowledge merging or influencing beliefs and practices of the educator (Grossman, 1990; Magnusson et al., 1999; Park, Jang, Chen, & Jung, 2011; Park & Oliver, 2008; Shulman, 1986, 1987). The resulting construct of PCK can support learning specific to the educator, student, and content of instruction (Grossman, 1990; Park et al., 2011; Park & Oliver, 2008).

**Constructs of PCK.** Shulman (1986, 1987) identified seven components that function in teacher planning and implementation of instruction. Six of these components include knowledge of the subject matter or content to be taught, knowledge of methods or pedagogy to present content information, knowledge of the intended curriculum, knowledge of the audience, knowledge of the context of the teaching and learning, and knowledge of the intended outcomes of instruction (Shulman, 1986, 1987). The seventh component consists of an interaction of the
knowledge of content or subject matter information and the knowledge of methods or pedagogy. This interaction forms what Shulman (1986, 1987) termed PCK.

The establishment of PCK was based on Shulman’s (1986, 1987) observations of and interviews with teachers about choices made prior to and during instructional sequences. Shulman (1986, 1987) noted content knowledge that he identified as what the educator needs to know about the subject or information to be taught. Shulman (1986, 1987) also identified the pedagogical knowledge of educators that encompassed the methods of teaching that allowed educators to communicate content information to a particular group of students (Shulman, 1986, 1987). While content and pedagogy had existed separately in discussions of teacher effectiveness, evaluation, and certification, Shulman (1986, 1987) proposed that the confluence of content and pedagogy was an important consideration for successful teaching and learning.

**Revisions of PCK.** Depaepe, Verschaffel, and Kelchtermans (2013) reported that the theory of PCK was too narrow and needed to expand beyond the initial content and pedagogy identified by Shulman (1986, 1987). In reviewing models of PCK that emerged since his initial conceptions, Shulman (2015) agreed that student outcomes and non-cognitive domains be included into models of PCK. Friedrichsen, Van Driel, and Abell (2010) broadened the theory of PCK to include teacher beliefs as factors impacting instructional decisions. Zembylas (2007) addressed another non-cognitive domain by including the emotional aspects of teaching and learning as components of PCK. The introduction of non-cognitive areas of teaching and learning address the narrow scope of PCK and allow an improved understanding of context and interactions with students (Depaepe et al., 2013; Friedrichsen et al., 2010; Shulman, 2015; Zembylas, 2007).
Models of PCK as applied to science teachers and science instruction include components of teacher orientations and assessments of outcomes evidenced by Grossman (1990), Magnusson et al. (1999), and Park and Oliver (2008). Grossman (1990) included teacher orientations within PCK, which was maintained and expanded in the subsequent model developed by Magnusson et al. (1999). Drawing from Magnusson et al. (1999), Park and Oliver (2008) included assessment as one component of a pentagon model that also includes curricula and programs, purposes of education, student conceptions and misconceptions, and instructional strategies. Kind (2015) reported that continuing research and applications of PCK will continue to clarify and adapt models that contribute to the understanding of educator knowledge and practice.

**Disciplinary literacy and PCK.** The application of Shulman's (1986, 1987) theory of PCK was consistent with Moje's (2015) proposals for teaching disciplinary literacy in science. Moje (2015) acknowledged that shifts in literacy instruction can present challenges for educators trained within a discipline. Shanahan and Shanahan (2008) focused efforts on preparing preservice educators for changes in literacy instruction, but such efforts neglected the needs and challenges posed by shifting instruction of in-service educators. Various studies demonstrated the potential of PCK to improve knowledge and pedagogy relevant to science instruction (Goldschmidt & Phelps, 2010; McNeill & Knight, 2013; Stasinakis & Athanasiou, 2016).

The instruction of disciplinary literacy in science requires science content knowledge, literacy knowledge, and pedagogy for teaching both content and literacy. The teaching of disciplinary literacy through practices authentic to the science discipline, such as science and engineering practices outlined by the NRC (2012), aligned with the constructs of PCK (Cooper et al., 2015; Grossman, 1990; Houseal et al., 2016; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1986, 1987). Changing practice to integrate disciplinary literacy instruction includes
consideration of student characteristics and the diversity of academic and cultural contexts (Falk, 2012; Hansen, Mavrikis, & Geraniou, 2016; Stasinakis & Athanasiou, 2016). Hansen et al. (2016) included PCK and related a deeper understanding of content to reconsiderations of presentations to students, therefore positively impacting PCK. Similarly, Stasinakis and Athanasiou (2016) documented the inclusion of teacher understanding of students as a practice that enhanced PCK.

Beyond impacts of learner characteristics, understanding the PCK of an educator is related to experiences of and contexts surrounding the educator (Cooper et al., 2015; Grossman, 1990; Houseal et al., 2016; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1986, 1987). The educator must function within organizational structures of an institution. Contextual and environmental factors develop and enhance PCK based on abundance or limitations of support, physical structures, and other factors of curricula, scheduling, and expected outcomes (Chowdhary, Liu, Yerrick, Smith, & Grant, 2014). Educator experiences can be revealed through background and training. Educator background can form components of PCK that have a bearing on functioning in varied contexts and may be related to factors such as culture, years teaching experience, types of teaching experience, content area expertise, and other experiences (Ben-Peretz, 2011; Goldschmidt & Phelps, 2010; Rozenszajn & Yarden, 2014; Schneider & Plasman, 2011). Understanding the PCK of an educator related to disciplinary literacy in science includes a general understanding of educator background and experience.

Application of teaching content and skills by in-service educators can be investigated to inform knowledge and practices that facilitate shifts in disciplinary literacy instruction (Brozo et al., 2013; Moje, 2015; Roseler & Dentzau, 2013; Shanahan & Shanahan, 2008; Zhang, Parker, Koehler, & Eberhardt, 2015). This research supports understanding practices of in-service
science educators involved in the process of shifting instruction. Researchers aid the understanding of disciplinary literacy to inform current practice and needs of educators. A system of engaging, eliciting, examining, and evaluating practices of educators related to disciplinary literacy as proposed by Moje (2015) supported such research and necessary changes in practice. Moje (2007, 2015) stressed the need for knowledge about both content and literacy consistent with Shulman's (1987) identification of PCK as integral. Drawing from Moje (2007) and Shulman (1987), disciplinary literacy instruction embedded in content instruction was impacted by the teacher’s PCK of both content and literacy. Understanding of interactions within disciplinary literacy instruction in science courses was furthered through this research that explored the integration of literacy and content instruction through tasks authentic to uses by real-world science experts and demonstrated in the application of Shulman’s (1986, 1987, 1998) theory of PCK to disciplinary literacy and content instruction (Fang & Coatoam, 2013; Moje, 2007).

**Methodology.** The implementation of disciplinary literacy in science classrooms requires an understanding of the knowledge and actions of science teachers. The understanding of current teacher actions does not rely on the testing of specified interventions but rather requires an exploration of current programs and actions (Stake, 1995; Yin, 2014). This exploration of the methods that teachers incorporate in planning and implementing instruction of science and literacy therefore fits within the qualitative research paradigm of investigating a problem or phenomenon (Stake, 1995; Yin, 2014). The investigation of open-ended questions that explore what is happening in current contexts aligns with qualitative research methodology.

The exploration of disciplinary literacy implementation is a broad topic that spans the context of discipline, grade levels, and the practices of teachers (Fisher & Ivey, 2005). Therefore,
the exploration of disciplinary literacy needs to be bounded to allow for in-depth analysis. The application of qualitative case study methods provided a means for bounding the research within each case (Stake, 1995; Yin, 2014). Findings of single case study methods can be expanded through the use of multiple case study methods (Yin, 2014). Multiple case study methods provide opportunities for understanding individual cases as well as options for comparing and contrasting data between cases (Yin, 2014). The use of case study methods can be used to gather in-depth data that can inform the understanding of actions applied by participants in the given contexts (Stake, 1995; Yin, 2014).

Shulman (1987, 1998) promoted the use of case knowledge for reflecting on, teaching, and learning about experiences that support the development of PCK. Building case knowledge requires the collection and analyses of case study data (Shulman, 1998; Stake, 1995; Yin, 2014). Qualitative methods, including case study methods, can reflect experiences and understanding of educator actions that can inform considerations of PCK in the researched context and possibly inform future research (Shulman, 1987; Stake, 1995). Additionally, Shulman (1998) presented the value of case study in illustrating the complexity of pedagogy through documentation and analyses of a series of experiences to be used in reflective practices that improve PCK. The PCK that results in the implementation of disciplinary literacy instruction is not fully explicated in literature, thus indicating the need for additional study of disciplinary literacy and educator PCK that influence the implementation of disciplinary literacy (Buczynski & Hansen, 2010; Chapoo, Thathong, & Halim, 2014; Chowdhary et al., 2014; Moje, 2015; Rozenszajn & Yarden, 2014; Shanahan & Shanahan, 2008; Stasinakis & Athanasiou, 2016). A multiple descriptive case study was used to describe educator actions in the implementation of disciplinary literacy in a middle level science classroom (Yin, 2014).
Research Questions

The lack of significant improvement in student literacy achievement evidenced by measures reported by NCES (2017) resulted in alternative approaches to literacy instruction centered on disciplinary literacy instruction (Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). Meeting the need of changing literacy instruction in the science classroom requires a better understanding of science teacher PCK for science and disciplinary literacy. Shulman’s (1986, 1987) theory of PCK informed the overarching research question of the exploration of teacher actions and decision-making based on understanding of content and pedagogy for disciplinary literacy instruction in the science discipline. Research on disciplinary literacy instruction in middle level science classrooms was driven by the following overarching research question: “What do science educators in an urban middle school know about and do to implement disciplinary literacy instruction in the science classroom?”

Based on this research question, the study included five sub-questions. The sub-questions developed from the major components of literacy instruction identified in the literature. The first research sub-question drew on Shulman’s (1986, 1987) theory of PCK by including the knowledge of literacy content and pedagogy. Research sub-questions two through four focused on the components of literacy instruction identified in literature and included reading, writing, and speaking and listening (Lent, 2015; NGACBP & CCSSO, 2010; Zygouris-Coe, 2012). The inclusion of science practices from the literature informed the fifth research sub-question (Houseal et al., 2016; NGSS Lead States, 2013). The research sub-questions were the following:

**RQ1**: What are the prior disciplinary literacy knowledge, training, and development experiences of science educators?
**RQ2:** What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of reading skills?

**RQ3:** What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of writing skills?

**RQ4:** What do participating science educators at the urban middle school do in the implementation of science instruction to support speaking and listening skills?

**RQ5:** What do participating science educators at the urban middle school do in the implementation of science instruction to integrate literacy skills and science and engineering practices?

**Delimitations and Limitations of the Study**

The study of disciplinary literacy is a broad topic that cannot be adequately addressed in a single study (Fang & Coatoam, 2013; O’Brien, Stewart, & Moje, 1995; Zygouris-Coe, 2012). Qualitative methodology allowed for the exploration of disciplinary literacy exploration within the science programs at the selected site (Stake, 1995; Yin, 2014). Multiple case study methods outlined by Yin (2014) were used to structure the exploration of disciplinary literacy in science classrooms. In the completion of this study, the focus was narrowed in order to facilitate the exploration of disciplinary literacy.

**Delimitations.** Delimitations in research include factors that are within the control of the researcher and can impact the outcomes of the study, including study boundaries defined by the researcher (Bogdan & Biklen, 2007). One delimitation in this study was the focus on educator knowledge and actions related to disciplinary literacy, including reading, writing, and speaking and listening, as integrated through science and engineering practices (Houseal et al., 2016; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Zygouris-Coe, 2012). The current
exploration focused on addressing the problem of disciplinary literacy instruction. Due to the focus on the implementation of instruction, the study was narrowed to educator PCK and perceptions of disciplinary literacy (Fang & Coatoam, 2013; Houseal et al., 2016; Shulman, 1986, 1987; Zygouris-Coe, 2012). The study did not include student reactions to instruction or student outcomes as the inclusion would have broadened the study and diminished the focus on the teacher actions (Stake, 1995; Yin, 2014).

Disciplinary literacy approaches address all content areas (Lent, 2015). However, researching disciplinary literacy in all content areas is too broad for a single study. Therefore, the study was narrowed to the science content area. The science content area has been recently impacted through the creation and adoption of the CCSS that include literacy standards for science (NGACBP & CCSSO, 2010). Furthermore, the development of the NGSS impacted instructional approaches in science (NGSS Lead States, 2013). Due to the potential for changing instruction in science due to curricular re-alignment with standards, the science discipline was chosen. The current environment in science education provided opportunities for science educators to implement changes in pedagogy related to science and disciplinary literacy (Goldman et al., 2016; Houseal et al., 2016).

As a result of the focus on science education, site and participant selection included science courses and science teachers. The site was limited to a single location that included multiple science courses at different levels. These courses were taught as separate content-specific classes. The site was chosen for convenience to the researcher in accessing the site (Stake, 1995). Participant selection in this study was limited to educators with state science teaching certifications or highly qualified status as determined by the state and implementation of disciplinary literacy instruction. Some prior research has examined preservice educator
development of literacy instruction (Cook & Dinkins, 2015; Moje, 2015; Shanahan & Shanahan, 2008, 2015). However, this study will limit the scope to in-service science teachers currently teaching at the middle level to address the pedagogy and content knowledge evident in instruction as a means of exploring and describing the implementation of disciplinary literacy in science classrooms.

Findings can be impacted by the delimitations of the study. The focus of the study on the planning and instruction implemented by participants did not include student achievement data. Therefore, conclusions of this study could be limited to educator actions independent of student achievement measures. Additionally, the data were limited to in-service teachers of science. Conclusions could be focused on teacher instruction within the science discipline and not applied across disciplines. Boundaries of the study limited data collection to a single urban middle school, so findings and conclusions may not be generalized beyond the identified setting.

Limitations. Limitations of research are factors that cannot be controlled by the researcher and may be considered weaknesses of the study (Bogdan & Biklen, 2007). Qualitative methods were used to explore disciplinary literacy instruction and were not intended to be broadly generalizable (Stake, 1995; Yin, 2014). This case study research may be limited in broad generalizability, but information was presented with descriptions that allow for transferability to other situations (Stake, 1995; Yin, 2014). Case study data can support explorations and information that go beyond evaluations of quantitative methods (Stake, 1995; Yin, 2014). Descriptions that include thick and rich description will be used to provide context and information that support the transferability of the study (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).
A second limitation of qualitative case study research is the time required for completing the research. Case studies can require long-term data collection to reach a saturation of data (Bogdan & Biklen, 2007). The ongoing data collection and analysis can extend beyond the often pre-determined implementation and assessment of an intervention in quantitative studies (Campbell & Stanley, 1963). Data may be impacted as a shorter time limits the amount of data available to the researcher. Due to the format of this study, data collection was limited to nine weeks to meet the time requirements of the dissertation process.

A final limitation of qualitative methodology is the positioning of the researcher (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). Analysis and interpretation of findings may be influenced by the experience and bias of the researcher. The impact of researcher experience and bias can be minimized through an acknowledgement of possible factors and processes to check data analysis and interpretation. In this study, the position of the researcher as a former middle level science and current secondary level science teacher was stated and efforts such as triangulation and member-checking were used to minimize impacts of the researcher position on data interpretation (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

**Significance of the Study**

Fang and Coatoam (2013) offered an overview of disciplinary literacy rooted in the conceptual applications and promise of disciplinary literacy instruction, which include an acknowledgement of research-based strategies and practices relating to each construct of literacy instruction and a recommendation for continued research on disciplinary literacy practices in the classroom. Building on this recommendation for further research, exploration of teacher practices drew on the approaches to disciplinary literacy outlined by Houseal et al. (2016) and Norris and Phillips (2003). Disciplinary literacy instruction in science can be viewed as the
fundamental processes of language use in reading and writing described by Norris and Phillips (2003) as a means for engaging students in science behaviors that apply practices and thinking structures to build cognitive processes associated with the science discipline and to construct and share scientific knowledge (Houseal et al., 2016). Research on how educators currently implement disciplinary literacy instruction can impact scholarly research and literature, teacher practice, and policy and decision-making.

**Significance for scholarly research and literature.** This study can contribute to the scholarly research and literature on disciplinary literacy in four ways. First, the study focused on exploring teacher views and experiences of disciplinary literacy instruction and can add to literature about the implementation of disciplinary literacy by describing methods for how they incorporate disciplinary literacy in science as recommended by Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015). The exploration can describe methods that contribute to or inhibit the facilitation of disciplinary literacy instruction. Beyond literacy components, the exploration of disciplinary literacy in science classrooms transitioning to the NGSS may improve understanding of teachers’ views on the integration of literacy and science (Fang & Coatoam, 2013). Therefore, the study can draw on the experiences and views of middle level science teachers to contribute to research literature on teacher PCK for disciplinary literacy in science (Shulman, 1986, 1987).

In addition to understanding teacher views and experiences on disciplinary literacy, the study can provide an understanding of practices preferred by teachers and used in disciplinary literacy instruction in science. The study can contribute examples of methods or pedagogy for disciplinary literacy that are currently lacking in scholarly literature (Fang & Coatoam, 2013; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). Exploration of pedagogies can aid in
moving beyond the conceptualizations of disciplinary literacy presented by Shanahan and Shanahan (2008, 2015) and may address the need for understanding practices as identified by Fang and Coatoam (2013). The addition of these pedagogies to scholarly research can aid in the application of disciplinary literacy beyond the contexts of this study.

The study can also contribute to scholarly research and literature by outlining connections between disciplinary literacy instruction and science content standards (Houseal et al., 2016; NGACBP & CCSSO, 2010; NGSS Lead States, 2013). As participants in the study were preparing for and beginning to implement changes in instructional approaches in response to state and district adoption of the NGSS (NGSS Lead States, 2013). Examples of embedding literacy in science instruction aligned with the NGSS can represent an area of weakness in current scholarly literature (Fang & Coatoam, 2013). The application of disciplinary literacy by the participants within the authentic dimensions of instruction outlined in the NGSS can contribute to the scholarly literature (Houseal et al., 2016; NGSS Lead States, 2013).

Lastly, contributions to scholarly research may include supporting transitions from the conceptualization of disciplinary literacy presented by Shanahan and Shanahan (2008, 2015) to classroom practice. Research acknowledged the need for expanding methods of literacy instruction (Brozo et al., 2013; Faggella-Luby et al., 2012; Fang & Coatoam, 2013; Houseal et al., 2016; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). Brozo et al. (2013) proposed implementation of disciplinary literacy as a balanced approach with other literacy instruction, such as content area literacy. Understanding how educators balance various needs of both literacy and science skill development can contribute to the scholarly literature. These contributions addressed the planning and implementation steps taken by teachers to create meaningful literacy instruction in the science classroom.
**Significance for practice.** Practices of science educators can be impacted by understanding the varied forms of text and instructional approaches used in science (Anderson, 1999; Houseal et al., 2016; Norris & Phillips, 2003). As science teachers adopt varied instructional approaches for literacy related to text, practices can move beyond the use of textbooks and articles to other forms of reading and writing that include the use of diagrams, graphs, charts, and data. Understanding how participants adapt to instructional standards and pedagogical reforms can improve opportunities for disciplinary literacy instruction and application of literacy skills to a variety of texts (Anders & Guzzetti, 2005; Anderson, 1999; Linderholm, Therriault, & Kwon, 2014; Norris & Phillips, 2003; Vellom & Anderson, 1999). The literacy practices of teachers can be impacted through descriptions of successes and challenges presented in research, including this study (Anderson, 1999; Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015).

Teacher practice can also be impacted by an evolving understanding of how literacy is or is not being implemented in a science classroom. Through understanding educator knowledge and implementation of literacy, educator practices can be refined to incorporate science and engineering practices that promote fundamental literacy in the progression toward the derived components and holistic understanding of science concepts and theories (NGSS Lead States, 2013; Norris & Phillips, 2003). Reflections of educators can reveal reasons for decisions based on educator PCK (Shulman, 1987).

Finally, the current practices of educators can be related to PCK built on prior learning and inform future areas of development necessary in furthering both understanding of disciplinary literacy and classroom practices (Fang & Coatoam, 2013; Shulman, 1986, 1987). Research on current practices can provide support for implementation of both practices and
policies, thereby supporting changes in practices to meet the needs of students through improved
disciplinary literacy instruction as outlined by Moje (2008, 2015) and Shanahan and Shanahan
(2008, 2015). Support for these changes may include identifying the professional development
necessary to meet the needs of PCK to impact the practice for individual teachers (Shulman,
1986, 1987). The cultivation of PCK for disciplinary literacy instruction can improve
professional practices for teaching literacy as used by experts in the science discipline. The
developed understanding can move disciplinary literacy instruction from conceptualization to
practical implementation in the classroom (Brozo et al., 2013; Houseal et al., 2016).

**Significance for policy and decision-making.** Contributions to research may include
furthering the understanding of disciplinary literacy implementation in science classrooms (Fang
& Coatoam, 2013; Houseal et al., 2016). As this understanding is developed, the knowledge of
disciplinary literacy implementation can expand beyond practices in individual classrooms to
inform overall systems of literacy instruction. The definition and implementation of disciplinary
literacy can be used in making decisions concerning curriculum, instruction, and evaluation of
literacy instruction in science (Houseal et al., 2016). Both teachers and administrators may use
findings from the study to initiate discussion of teacher practices for integrating literacy
instruction in discipline-specific classrooms. The understanding of disciplinary literacy
implementation can therefore be applied in a context broader than individual classrooms (Fang &
Coatoam, 2013; Houseal et al., 2016).

Current literature presented studies focused on the pieces of the disciplinary literacy
instructional puzzle, but few studies reported on the broad picture of classroom practices that
integrated all pieces in the context of a middle level science classroom, especially from the
perspectives of classroom educators and students (Hand, Yore, Jagger, & Prain, 2010; Houseal et
al., 2016; Klein & Kirkpatrick, 2010; Klein & Unsworth, 2014; Michaels et al., 2008; Moje, 2007, 2008; Rupley, 2010; Zmach et al., 2006). To overcome implementation issues associated with content area literacy and generalized strategies as reported by O’Brien et al. (1995) and Zygouris-Coe (2012), this study can contribute to examples of the transitions from content area to disciplinary literacy instruction. Research included components of educator attitudes and beliefs, training, planning, steps of implementation, and reflection that can be applied at institutional levels in support of effective literacy instruction (O’Brien et al., 1995; Tang, 2016; Zygouris-Coe, 2012). The understanding of differences between content area and disciplinary literacy implementation can provide information that informs decisions and policies of literacy instruction and support at school and district levels.

Furthering the connections of literacy and science practices can support current standards-driven curricula and instruction while contributing to the need for understanding and transforming the conceptual nature of disciplinary literacy into meaningful instruction consistent with specific disciplines (Fang & Coatoam, 2013; Houseal et al., 2016). Disciplinary literacy instruction can be supported by the creation of curricula that connects the expectations of science standards, such as NGSS, with disciplinary literacy applications in the science classroom. Beginning with decisions regarding the adoption and implementation of the NGSS and the CCSS, policies can support the development of instructional approaches and teacher PCK that further the implementation of standards through application of balanced literacy instruction that includes disciplinary literacy (Brozo et al., 2013; Faggella-Luby et al., 2012; Fisher & Ivey, 2005). Understanding of disciplinary literacy instruction in science based on the findings of this study can be applied to support the adoption and implementation of curriculum for science and literacy instruction.
The successful implementation of disciplinary literacy instruction requires policy decisions that provide effective supports, including professional development, administrative support, and structural support within the school day and curricula. This study may demonstrate effective or ineffective supports that can aid educators in internalizing the shifts in their instructional practices. Documentation of changing instructional practices can provide opportunities for science and literacy learning opportunities aligned with reform efforts (Abd-El-Khalick et al., 2004; Fisher & Frey, 2008; Moje, 2007; NRC, 2012; NGSS Lead States, 2013; O’Brien et al., 1995; Zygouris-Coe, 2012). However, the outcomes of these supports manifested in the specific actions of educators in classroom implementation of disciplinary literacy in science are lacking in literature, thus prompting the call for additional research and supporting the significance of this research (Faggella-Luby et al., 2012; Fang & Coatoam, 2013; Shanahan & Shanahan, 2012).

**Definition of Terms**

**Content area literacy.** This term is defined as the teaching of general reading and writing strategies to be applied in any discipline or content class rather than literacy practices specific to a discipline (Shanahan & Shanahan, 2008).

**Content knowledge.** This term is defined as the understanding of the topics and concepts that are represented in a discipline (Shulman, 1987, 1986).

**Disciplinary literacy.** This term is defined as the use and understanding of applications in a discipline that reflect the language, vocabulary, discourse and practices of the discipline (Moje, 2015).
**Pedagogical content knowledge.** This term is defined as the interaction of specific teaching practices with specific leaning in a discipline that results in the transformation of content for student understanding (Shulman, 1986, 1987)

**Pedagogical knowledge.** This term is defined as the understanding of the methods and processes of instruction (Shulman, 1986, 1987).

**Science and engineering practices.** This term is defined as understandings and skills presented in the Next Generation Science Standards (NGSS) that parallel the skills used by expert scientists and engineers to learn, apply learning, identify problems, and work toward solutions (NGSS Lead States, 2013).

**Organization of the Study**

The research study follows the traditional five-chapter presentation of a dissertation. Chapter 1 provided an introduction of the contemporary problem in middle school education that served as the basis for the chapter. The chapter continued with discussions on the background and contextualization of the issue, along with the problem statement that addressed the need for improving literacy instruction in the disciplines. The problem flowed into the purpose of exploring the disciplinary literacy instruction implemented in middle level science classrooms in an urban middle school in the United States. Then, the researcher discussed the use of the theory of PCK (Shulman, 1986) and its revisions (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008) as a framework for the study. Next, the researcher introduced the qualitative case study design used for data collection, along with the theoretically based research questions answered from the study. The researcher discussed the delimitations and limitations of the study. The researcher provided discussions relative to the delimitations and limitations of the study. Then, the researcher justified the importance of the study in the presentation of the significance
of the study. Next, the researcher provided a list of key terms used in the manuscript to familiarize the reader with the topic-specific vocabulary. After a description of the study’s organization, the chapter is closed with a summary of the substantive content from the discussions.

A review of relevant literature and the theoretical framework is presented in the Chapter 2. Literacy instruction in science will be discussed as supported by the literature beginning with content area literacy instruction and progressing through changing approaches to disciplinary literacy instruction. The application of disciplinary literacy to science instruction and relationships to science standards and practices will be presented. Following the application of disciplinary literacy in science instruction, critiques of disciplinary literacy instruction will be presented. The role of educators in disciplinary literacy instruction drawn from the literature will be summarized. Flowing from educator roles in disciplinary literacy instruction, the theoretical framework of Shulman’s (1986, 1987) PCK will be outlined followed by critiques of and revisions to PCK. The integration of PCK and disciplinary literacy will be presented as related to both science and literacy instruction. The review of literature and the theoretical framework will be presented at the end of Chapter 2.

Chapter 3 provides identifications and explanations of the methods used in the study. Chapter 4 presents data analysis and findings of the study. Chapter 5 presents the summary, conclusions, implications, and suggestions for future research.

**Chapter Summary**

Since 1992, literacy achievement of students in the United States has not shown expected improvement as measured by national standardized assessments (NCES, 2017). The lack of growth in literacy scores has resulted in researchers calling for changes to approaches of literacy
instruction across disciplines, including in science. Researchers have recommended changing instruction to embed literacy instruction in ways that are consistent with uses of literacy by experts in the discipline, termed disciplinary literacy (Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015; Zygouris-Coe, 2012). The disciplinary literacy approach remains a primarily conceptual form of instruction in much of the literature (Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015; Zygouris-Coe, 2012). The conceptual nature of disciplinary literacy requires additional research about implementation in science classrooms.

As proposed by Fang and Coatoam (2013), current literature did not address the instructional changes necessary to align literacy instruction in science with the disciplinary literacy concepts presented in the work of Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015). Fang and Coatoam (2013) suggested the need for additional research necessary to understand the comprehensive changes to instruction that result from the emphasis on literacy instruction through science and engineering practices. Consistent with the suggested need of understanding the shifts in instruction, the purpose of this qualitative case study was to explore the disciplinary literacy instruction implemented in middle level science classrooms in an urban middle school in the United States to address the over-arching research question, “What do science educators in an urban middle school know about and do to implement disciplinary literacy instruction in the science classroom?” The exploration of educator actions in planning for and implementing literacy instruction in science classes can add to understanding of successful implementation of and challenges to disciplinary literacy instruction.

The study focused on educator actions, including planning, implementation, assessment, and reflection, and drew on Shulman’s (1986, 1987) theory of PCK in the investigation of how educators implement disciplinary literacy instruction. Using qualitative case study methods, this
study described and analyzed educator actions. The analyses contribute to existing gaps in the literature through the investigation of how science teachers respond to disciplinary literacy in their planning, implementation, and reflection on instruction. Findings from the study contributed to scholarly research and literature, enlightened researchers and educators of current practices, and provided understanding to impact policy and decision-making processes. Findings also inform future research to continue improving instructional practices for disciplinary literacy in science classrooms.
Chapter 2: Review of the Literature

Science instruction is one of the four core learning areas that include English language arts, mathematics, science, and social studies. As a core content discipline, science has been identified as a subject that can support literacy development (Fisher & Ivey, 2005; O’Brien et al., 1995). Prior approaches to content area literacy instruction focused on generalized strategies that were taught independently of content and were intended to be transferred between disciplines (Fisher & Ivey, 2005; Herber, 1970; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). However, Fisher and Ivey (2005) stated that generalized content area literacy strategies have not produced expected gains in student achievement.

Data from across the United States presented by the NCES (2017) demonstrated average reading scaled scores ranging between 260 and 265 from 1992 to 2015. These average reading scores have not, with the exception of 2012, represented statistically significant differences for over the last 20 years as reported on the NAEP (NCES, 2017). Furthermore, average reading scores are below the threshold of a proficient score or below a scaled score of 243 on the NAEP assessments (NCES, 2017). The lack of growth in reading scores resulted in reforms in literacy instruction such as those presented by Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015).

In this chapter, literature related to content area and disciplinary literacy instruction will be reviewed prior to presenting current definitions of disciplinary literacy in science as related to reading, writing, and speaking and listening skills. Eight science practices as outlined in NGSS (NGSS Lead States, 2013) will be defined as presented in literature. Disciplinary literacy instruction as a beneficial means of connecting literacy and science practices within science is presented in literature and will be discussed. Critiques of disciplinary literacy from the literature
will follow the beneficial impacts of disciplinary literacy. The role of preservice and in-service educators in implementing disciplinary literacy instruction will provide context for the study of educator planning and implementation of literacy instruction.

After reviewing disciplinary literacy and educator roles, Shulman’s (1986, 1987) theory of PCK to disciplinary literacy instruction in science will be presented. The application of the theory of PCK will provide a framework for reviewing and interpreting teacher content and pedagogical knowledge surrounding the implementation of disciplinary literacy in science. Critiques of Shulman’s (1986, 1987) theory will be presented as well as applications of PCK to science instruction (Grossman, 1990; Magnusson et al., 1999; Park et al., 2011). Science and literacy PCK will be presented prior to a summary of PCK. The chapter will conclude with a summary of literature reviewed and the theoretical framework.

**Literacy Instruction in Science**

The use of literacy skills in science is one dimension of instruction as evidenced in the science and engineering practices of the NGSS (NGSS Lead States, 2013) and in other national, state, and local standards in the United States and countries throughout the world. These movements have renewed the focus on literacy instruction in science through the identification of literacy as an essential component of instruction across disciplines (Drew & Thomas, 2018; Faulkner, 2012; Hannant & Jetnikoff, 2015; MacMahon, 2014; NGACBP & CCSSO, 2010; Tang, 2016). Implementation of literacy instruction in content areas stemming from this renewed focus has evolved, moving away from content area literacy practices focused on generalized strategy instruction. Moje (2008) and Shanahan and Shanahan (2008) advocated for disciplinary literacy instruction focused on the integration of literacy practices authentic to the uses exhibited by experts in each discipline.
Literacy is often defined as inclusive of reading and writing. Many new standards also include speaking and listening skills (Fisher & Ivey, 2005; NGACBP & CCSSO, 2010; Zygouris-Coe, 2012). While these skills constitute the basis of literacy, application of skills in scientific contexts represent integration of literacy in meaningful ways consistent with how science experts use literacy, including uses within the social contexts of the discipline (Moje, 2008; Shanahan & Shanahan, 2008; Sorvik, Blikstad-Balas, & Odegaard, 2015). This integration forms the domain of science skill labeled by Norris and Phillips (2003) as "fundamental science literacy" (p. 224) and serves as a gateway to learning science knowledge, concepts, and facts. When considering disciplinary literacy instruction in science, focus on reading, writing, and speaking and listening skills can be viewed in the context of science and engineering practices (Houseal et al., 2016; NRC, 2012; NGSS Lead States, 2013; Norris & Phillips, 2003; Wilson, Smith, & Householder, 2014). Integration of literacy instruction in science requires educator understanding of both content and pedagogy necessary for science and literacy teaching and learning.

**Content area literacy instruction.** Herber (1970) proposed that every teacher (e.g., disciplinary or subject specialist) is a teacher of reading with a focus on transferable skills and termed content area literacy. In this view, all educators are reading educators. Teaching literacy in content classes, termed content area literacy, began with the teaching of reading strategies focused on decoding and comprehension and was broadened to include the teaching and applying of generalized strategies for both reading and writing (Goldman et al., 2016; Fang, 2014; Fang & Coatoam, 2013; Moje, 2015; O’Brien et al., 1995; Shanahan & Shanahan, 2008). The use of content area literacy through general strategies was expected to aid students in reading discipline-specific texts or completing disciplinary writing tasks. The goal of content
area literacy is to teach general reading and writing strategies that are then transferred to other contexts and content areas outside of the discipline or course in which the strategies were taught (Fang, 2012; Fang & Coatoam, 2013; Goldman et al., 2016; Houseal et al., 2016; Moje, 2015; O’Brien et al., 1995).

The content area literacy approach outlined by Herber (1970) has been implemented across content areas, including the science discipline to varying degrees (Drew & Thomas, 2018; Fisher & Frey, 2008; Fisher & Ivey, 2005; O’Brien et al., 1995). The use of strategies in middle level science classes has been documented to include graphic organizers, anticipatory activities, read-alouds and shared reading, and vocabulary instruction (Fisher & Frey, 2008; Roman, Jones, Basaraba, & Hironaka, 2016). An outside-in approach to literacy instruction applied generalized strategies in content areas. These generalized literacy strategies originated separate from disciplinary knowledge and practices and are then pushed into disciplinary instruction (Fang, 2012; Fang & Coatoam, 2013; Hannant & Jetnikoff, 2015; Ingram, Bumstead, & Wilson, 2016; Wilder, 2014).

**Changing literacy instructional approaches.** The intended goal of content area literacy instruction was to meet student needs for literacy skills through an approach that could be implemented across disciplines and transferred between disciplinary contexts (Fisher & Ivey, 2005; Herber, 1970; O’Brien et al., 1995). Content area literacy instruction has been found to have limitations in producing the desired student understandings, applications, and transfer of literacy within and between discipline-specific contexts due to institutional and organizational structures, time constraints, expectations of content teaching, and student and educator attitudes (Drew & Thomas, 2018; Fisher & Ivey, 2005; Ingram et al., 2016; Moje, 2015; Piercy & Piercy, 2011; Shanahan & Shanahan, 2008). Student needs based on past performance and expectations
expressed in standards and frameworks of the CCSS, the NGSS, and other state and locally developed standards present the need for a re-emphasis or adaptation in the approach to literacy in discipline instruction. Such a re-emphasis or adaptation in literacy instruction within disciplines can center on the use of literacy skills as applied authentically by disciplinary experts in their typical practices (Faggella-Luby et al., 2012; Fang, 2012; Moje, 2015; Shanahan & Shanahan, 2008).

In contrast to what Ingram et al. (2016) described as the “outside-in” (p. 104) application of general strategies in content area literacy, disciplinary literacy is an “inside-out” (p. 105) approach that begins with disciplinary goals and authentic tasks used to support the instruction of literacy skills and practices. Drew and Thomas (2018) found science educators to be more likely to implement disciplinary literacy instruction than content area approaches. As recommended by Fang (2014) and Lemke (2004), texts within the discipline of science can be broadly defined and move beyond written word. This broader definition of text can support building instruction that includes literacy skills used in comprehending and producing discipline-specific knowledge that parallels uses within the field of science (Fang, 2012; Hannant & Jetnikoff, 2015; Ingram et al., 2016; Moje, 2015; Norris & Phillips, 2003; Shanahan & Shanahan, 2008, 2015). Adaptations to or shifts in disciplinary literacy practice are embedded through modeling and instruction that demonstrates how experts in the discipline apply literacy skills and strategies (Fang, 2012; Moje, 2015; Rainey, Maher, Coupland, Franchi, & Moje, 2017; Shanahan & Shanahan, 2008; Yore, 2004).

**Disciplinary literacy instruction.** Content area and disciplinary literacy instruction has focused on four content areas: English language arts (ELA), mathematics, science, and social studies, with the majority of research focused on ELA disciplinary literacy (Faggella-Luby et al.,
McConachie (2010) presented a working definition of disciplinary literacy stating, “Disciplinary literacy involves the use of reading, reasoning, investigating, speaking, and writing required to learn and form complex knowledge appropriate to a particular discipline” (p. 16). This definition expanded beyond reading and writing about subject matter to include the use of literacy in constructing knowledge (Drew, Olinghouse, Faggella-Luby, & Welsh, 2017; McConachie, 2010; Prain & Hand, 2016).

Much of the research on disciplinary literacy has focused on the establishment of general characteristics, but research on individual disciplines is limited. Initial views of secondary science instruction that integrates disciplinary literacy demonstrate promise for methods that use literacy in methods authentic to the discipline (Fang & Coatoam, 2013; Fisher & Ivey, 2005; McConachie & Petrosky, 2010; Moje, 2015; Rainey et al., 2017; Shanahan & Shanahan, 2008; Tang, 2016). Current research provided perspectives on the implementation of disciplinary literacy demonstrated through educator scaffolding and instructional strategies related to disciplinary texts (Faulkner, 2012; Ingram et al., 2016; MacMahon, 2014; Tang, 2016). Strategies that are relevant to the discipline may be used by middle level science educators to incorporate literacy instruction authentic to the discipline, including varied levels of text, disciplinary communities within the classroom at differing levels, annotating texts, deconstructing and prioritizing components of questions or problems, giving and responding to feedback, close reading, graphic organizers, anticipatory activities, read-alouds, and vocabulary instruction (Fang, 2012; Fisher & Frey, 2008, 2014a, 2014b; Goldman et al., 2016; Rainey et al., 2017; Roman et al., 2016; Wilson et al., 2014). However, disciplinary literacy instruction moved beyond these generalized strategies to focus on an approach that is holistic and that addresses multiple texts, the expansive nature of text, and changes in how text is defined in science. The re-
emphasis of content in literacy instruction draws on comprehension, communication, and construction of knowledge as practices that produced authentic learning opportunities using literacy (Fang, 2012; Fang & Coatoam, 2013; Goldman et al., 2016). Additionally, the inclusion of literacy also allowed for use of critique to deepen learning about content (Henderson, MacPherson, Osborne, & Wild, 2015). When these components are applied in the science discipline, they represent processes that build on experiences in the discipline including reading, writing, and speaking and listening skills applicable to relevant language used for constructing and critiquing meaning and knowledge, which is consistent with recent standards and connections to science practices (Fang, 2012; Henderson et al., 2015; Houseal et al., 2016; MacMahon, 2014; McConachie & Petrosky, 2010; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Tang, 2016; Wilson et al., 2014).

Fang (2012) and Yore (2004) stressed the importance of the use of language within disciplines. The use of disciplinary language, both in vocabulary and presentation of information, has changed over time to meet the processes for creating and disseminating information and knowledge in the discipline (Fang, 2012; Goldman et al., 2016; Rainey, 2017). This changing use of language and sharing of information holds true in the science discipline, which contains language and methods of communication that meet the goals of the discipline through intertwining content and technical language. Chin, Yang, and Tuan (2016), Fang (2012), and Ingram et al. (2016) highlighted the sociocultural underpinnings of both language acquisition and disciplinary literacy. The sociocultural paradigm can be applied to the development of science instruction consistent with expectations in the NGSS as students are expected to be collaborative in constructing science knowledge (Houseal et al., 2016; NGSS Lead States, 2013; Wilson et al., 2014). Disciplinary literacy, as recommended by Moje (2008) and Shanahan and Shanahan
(2008), uses processes of learning that parallel the practices of scientists, thus supporting the interactions between learners in the construction of knowledge and the social aspects of scientific collaboration and highlighting the importance of language in content acquisition or knowledge construction (Berland & Reiser, 2008; Chi, 2009; Fang, 2012; Ford, 2008; Michaels, O' Connor, Sohmer, & Resnick, 1992; NRC, 2012; Prinsloo, 2018; Yore, 2004).

Acquiring and understanding the language of the discipline is a necessary component of disciplinary literacy as educators and students must develop a means for interacting with everyday, abstract, and metaphoric language in complex, disciplinary texts (Fang, 2012; Duit, 1991). As Fang (2012) suggested, texts within the science discipline can include a wide range of forms, including data sets and visual representations of data produced by inquiry methods of investigation and research. The key components of investigation and research within the science discipline result in disciplinary texts related to understanding, making sense of, and communicating about real-world events or phenomena. Such texts include a range of complexities and styles inherent in the science discipline and are important for student gathering of information for the construction of knowledge (Fang, 2012; McArthur, 2012). Due to the varied nature of text presented in the science discipline, the application of generalized strategies may assist learners in decoding the complexities of written disciplinary texts, but the understanding of context and content within the discipline may be overlooked by the use of such strategies. Learners can be better equipped to understand unique and complex language patterns, vocabulary, and writing styles of technical, disciplinary texts when disciplinary literacy is applied to authentic, discipline-specific tasks (Blikstad-Balas & Sorvik, 2015; Fang, 2012; Moje, 2015; Shanahan & Shanahan, 2008).
Yore (2004) stated that, “Scientists use language to access ideas, interact with other people, and construct science claims” (p. 83). To understand the implications of language use in classrooms, educators must be aware of the use of language, definitions of literacy, and application of literacy within the disciplines. As Moje (2008), Shanahan and Shanahan (2008), and Yore (2004) proposed, literacy use in the science discipline is integral to the learning of content and therefore must be understood in current contexts.

**Defining literacy in science.** Literacy instruction in the disciplines is a component of educator preparation and practice and has been supported through the development of content frameworks and standards at local, state, and national levels. As educators prepare for continued implementation of adopted standards, effective literacy instruction in the science discipline may be considered one key for successful integration of various components of the standards.

Differing definitions of literacy within science exist, ranging from Miller’s (1998) definition of science literacy as the “ability to read and write about science and technology” (p. 204) to definitions related to the use of literacy within the study and learning of science. However, effective literacy instruction in discipline contexts resulting from standards renews a focus on literacy and a meaningful integration of literacy and content skill leading to construction of knowledge and critique of science conclusions (Henderson et al., 2015; Houseal et al., 2016; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Wilson et al., 2014; Zygouris-Coe, 2012).

Within the United States, standards-based movements such as the CCSS and the NGSS have aided in linking literacy with practices in the disciplines. This link between literacy and disciplinary practices is evidenced in the literacy standards specific to the use and teaching of literacy within science and other technical subjects (NGACBP & CCSSO, 2010). The NGSS also supported the authentic use of literacy practices related to processes applied by scientists and
engineers (NGSS Lead States, 2013). While the CCSS and NGSS have been developed relative to education within the United States, various countries throughout the world have revised or developed standards and policies that emphasize literacy skills and practices in the disciplines. The inclusion of literacy by nations throughout the world contributes to a focus on literacy instruction and improvement of student achievement through literacy as a broad and relevant goal that goes beyond the United States and encompasses educational systems worldwide and spans all disciplines (Fang, Sun, Chiu, & Trutschel, 2014; Faulkner, 2012; Goldman et al., 2016; Hannant & Jetnikoff, 2015; MacMahon, 2014; McArthur, 2012; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Zhang & Shen, 2015).

Educator perspectives and understanding of literacy, both in general and as related to the discipline, can impact literacy instruction. While Herber (1970) initially focused on reading instruction in the disciplines, the view of literacy has broadened beyond reading skill and comprehension. Current literacy researchers and educators proposed opportunities for students to use reasoning and critical thinking through reading, writing, and other forms of communication (Anders & Guzzetti, 2005; Herber & Herber, 1993; Lemke, 2004; Moje, 2008, 2015; Piercy & Piercy, 2011; Shanahan & Shanahan, 2008, 2015; Yager, 2004; Yore, 2004). Drawing from the CCSS, literacy in current implementations centers on reading, writing, and speaking and listening processes and may be defined by the uses of these processes to obtain and evaluate information, construct knowledge, and communicate understandings (Drew & Thomas, 2018; NGACBP & CCSSO, 2010; Yore, 2004; Zygouris-Coe, 2012).

The incorporation of literacy instruction in disciplines originated with a focus on reading but has expanded as presented in standards and the practices of science (NGACBP & CCSSO, 2010; Yore, 2004; Zygouris-Coe, 2012). The components of literacy, including reading, writing,
and speaking and listening, are important in sensemaking of content as tools that support information processing and knowledge construction (Fang & Coatoam, 2013). The changing nature of literacy instruction is inclusive of the components of literacy and relevant to disciplines (Anders & Guzzetti, 2005; Fisher & Ivey, 2005; Moje, 2015; Shanahan & Shanahan, 2008; Yore, 2004).

**Reading.** Reading has been associated with approaches to instruction or strategies for decoding and comprehending written text (Faggella-Luby et al., 2012; Fisher & Frey, 2008; Herber, 1970). A focus on understanding text, especially discipline texts, can aid in developing general and content-specific knowledge. Pairing content with text can result in varied uses for and interactions with disciplinary text. Even though research supports such a pairing incorporated with the use of direct instruction to improve reading skills, a resulting lack of interest and lack of relevance can inhibit assimilation of content learning (Faggella-Luby et al., 2012; Lapp, Grant, Moss, & Johnson, 2013; Seifert & Espin, 2012; Shanahan & Shanahan, 2008; Zmach et al., 2006). Rather than using an approach based on generalized strategies that diminish the role of content, Cook and Dinkins (2015) and Rupley (2010) recommended embedding reading in ways that paralleled the processes used by scientists to interact with content and incorporate scientific thinking with communication of ideas through reading and writing.

Approaches that embed reading in the practices and processes of science can reduce the disconnect between reading and content instruction (Drew & Thomas, 2018; Faggella-Luby et al., 2012). Reading in science can be used to promote interactions with information that lead to the construction of knowledge (Anders & Guzzetti, 2005; Clinton & van den Broek, 2012; Cook & Dinkins, 2015; Enfield, 2014; McClune, Alexander, & Jarman, 2012). In disciplinary literacy, texts are varied and interactions with texts are through methods that seek to generate interest or
to use interest to impact the use of the text. Reading, analyzing, and applying information from texts can lead to an interpretation that builds science understanding (Anders & Guzzetti, 2005; Clinton & van den Broek, 2012; Cook & Dinkins, 2015; Enfield, 2014; McClune et al., 2012).

Reading as a means of interacting with information and building science knowledge is consistent with Yager’s (2004) proposition that reading in science is more than decoding and comprehension. Reading can be used to stimulate interest that drives inquiry into disciplinary content (Enfield, 2014; McClune et al., 2012). Reading can be viewed as one entry point into the processes of gathering and evaluating information, including inferencing, analyzing, and interpreting information that can be applied to disciplinary learning (Clinton & van den Broek, 2012; Fredlund, Linder, Airey, & Linder, 2014; Linderholm et al., 2014; Piercy & Piercy, 2011; Yager, 2004; Yore, 2004).

Information in science is presented in a variety of ways that include writing, diagrams, symbols, data sets, models, and equations. Since information is presented in varied methods, reading science must incorporate reading or obtaining information from these different sources (Anders & Guzzetti, 2005; Fredlund et al., 2014; Lemke, 2004; Roman et al., 2016). Reading can become part of doing science and engaging in the language of the science discipline (Lemke, 2004; Yore, 2004). Lemke (2004) identified the need for students to understand varied sources of information. To meet this need for students to engage with a variety of source materials, reading instruction must address the uses of reading in science to include diagrams, symbols, data, and equations (Anderson, 1999; Lemke, 2004; Norris & Phillips, 2003). Components of reading that include interpretation, comprehension, and application of information are applied to varied sources of information in science (Lemke, 2004; Norris & Phillips, 2003).
Re-emphasis of instruction with a focus on the implementation of disciplinary literacy relies on uses of reading that are authentic to the discipline or that are consistent with the uses of reading as expert scientists would employ in their work. Embedding reading reflective of expert uses moves beyond general strategies to provide context and meaning for reading skills. Instead of content supporting general strategies, application of reading can drive science practices that include investigation, thinking skill application, constructing knowledge, and communicating understanding (Anders & Guzzetti, 2005; Fang & Coatoam, 2013; Piercy & Piercy, 2011; Rupley, 2010; Shanahan & Shanahan, 2008; Yager, 2004; Yore, 2004).

**Writing.** Reading various forms and sources of text can facilitate the process of obtaining information, but scientists also produce text as a means of communicating and understanding information (Drew et al., 2017; Pelger & Nilsson, 2016; Prain & Hand, 2016). Although identified as an important communication tool in science, writing has been identified as a deficit area in both instruction and student achievement (Gillespie, Graham, Kiuhara, & Hebert, 2014; Graham, Capizzi, Harris, Hebert, & Morphy, 2014; Kiuhara, Graham, & Hawken, 2009; Yore, 2004). Disciplinary literacy instruction can incorporate goals consistent with content instruction to promote writing in varied forms and varied lengths (Klein & Ehrhardt, 2015; Klein & Kirkpatrick, 2010; Klein & Samuels, 2010; Lent, 2015; Piercy & Piercy, 2011). The adoption of standards and changes to instruction can result in methods of writing instruction that are collaborative, multimodal, and utilize varied resources leading to enhanced student reflection and learning (Lent, 2015; Pelger & Nilsson, 2016; Prain & Hand, 2016).

Writing frequently and in varied lengths are recommendations of writing instruction that can be incorporated in science classrooms to meet the goals of building skills and constructing science knowledge (Drew et al., 2017; Gillespie et al., 2014; Graham et al., 2014; Kiuhara et al.,
Klein and Samuels (2010) included the use of writing within disciplines to improve knowledge and strategies of writing. Constructivist approaches to writing and building knowledge can incorporate sources of information, multiple representations of information, and the linking of ideas from varied sources, which is consistent with expected outcomes in the CCSS and NGSS (Klein & Kirkpatrick, 2010; Klein & Samuels, 2010; NGACBP & CCSSO, 2010; NGSS Lead States, 2013).

Similar to the shifts of instruction in reading in the disciplines, writing instruction in the disciplines can focus on varied writing tasks and products. Focus on types, methods, and products of writing can be used by students learning to organize information and communicate as scientists within the expected formats of the discipline. Aligning the use of writing to disciplinary goals demonstrates authentic application of writing to support learning of science practices and content (Fang & Coatoam, 2013; Klein & Samuels, 2010; Pelger & Nilsson, 2016; Prain & Hand, 2016; Shanahan & Shanahan, 2008).

**Speaking and listening.** Learning through reading and writing is an incomplete representation of the application of literacy. Communicating both information about and understanding of content may be included in reading and writing but is also expressed in other visual and verbal forms of communication (Houseal et al., 2016; NGACBP & CCSSO, 2010; Zygouris-Coe, 2012). Michaels et al. (2008) described systems for promoting discourse, including speaking and listening skills, in classrooms to deepen thinking and understanding of content while positively impacting literacy skills.

Discourse as a component of disciplinary literacy instruction includes interactions between teacher and student as well as opportunities for student to student discussion. Research based on linguistic and sociocultural perspectives identify that students need to talk in the
process of making meaning (Mercer, 2010; van der Veen, van Kruistum, & Michaels, 2015). Students can use talk and collaboration centered on norms and processes to stimulate thinking that emerges from language. Language use in disciplines provides student with opportunities for engaging in social collaborations relevant to both content knowledge and disciplinary practices (Anders & Guzzetti, 2005; Michaels et al., 2008; van der Veen et al., 2015; Yore, 2004).

Yore (2004) underscored the importance of oral or verbal tasks to replicate the active processes of science and to supplement the uses of other forms of literacy in science instruction. Drawing from this position, constructing knowledge in science is, in part, a collaborative, social endeavor involving discourse between and within groups of scientists, thus incorporating speaking and listening skills. These practices can support scaffolds in science disciplinary literacy instruction and reflect the use of argumentation, evidence, and communicative practices of science experts (Anders & Guzzetti, 2005; Chin et al., 2016; Fisher & Frey, 2014a, 2014b; Michaels & O’Connor, 2015; Michaels et al., 2008; Michaels et al., 1992; van der Veen et al., 2015; Yore, 2004). Michaels and O’Connor (2015) suggested establishing structures for discourse within the learning community as a primary focus that can then be used as a tool for engaging with content and other forms of literacy.

The use of discourse in science instruction provides opportunities for engagement in multiple aspects of communication and literacy. When grounding a discussion in evidence and data, students must read, analyze, and interpret to create points of discussion and learning (Lemke, 2004; Michaels et al., 1992; van der Veen et al., 2015). Lemke (2004) included facial expressions, gestures, and body language as aspects of literacy that emerge through social interactions and discourse and in the building of scientific communities of learners. By applying
structures for facilitating and ensuring meaningful talk, content learning in science can be enhanced (Michaels & O’Connor, 2015; Michaels et al., 2008).

**Science practices.** Integration of disciplinary literacy in science, including reading, writing, and speaking and listening, in ways consistent with expert scientists’ use in their practice creates a framework for instruction inclusive of literacy, science skills, and content. This authentic use in practice is aligned to the inclusion of scientific practices in science instruction advocated in standards and policies (Fisher & Ivey, 2005; Houseal et al., 2016; Millar & Driver, 1987; NRC, 2012; NGSS Lead States, 2013). Therefore, the integration of disciplinary literacy may be viewed using science practices as related to the interpretation of information and communication of scientific knowledge.

In the United States, the NRC (2012) presented eight science and engineering practices to be incorporated into science instruction. Science practices revolving around questioning, modeling, experimentation, analysis and interpretation, gathering information, and communicating ideas can aid students in both developing or constructing knowledge of scientific concepts and fostering critical thinking and inquiry skills that contribute to learning beyond the classroom (Abd-El-Khalick et al., 2004; Miller, 1998; NRC, 2012; NGSS Lead States, 2013; Sorvik et al., 2015). To achieve these goals, the NRC (2012) practices are broad behaviors inclusive of knowledge and skill. These practices are important shifts in science instruction and discussion of practice in relation to disciplinary literacy in science. While not a singular process, progression of skills, or method, themes emerging from scientific inquiry can guide instruction that aids in the provision of opportunities for students to concurrently develop and apply skills and knowledge necessary for understanding and using science concepts and practices (Lemke, 2004; NRC, 2012; Yore, 2004).
**Questioning.** Scientists engage in practices directed at answering a question or solving a problem. Before the question or problem can be addressed, the question must be formulated or the problem identified. Critical consideration of information supports the practice of questioning and identifying problems by aiding students in critiquing information through the application of prior knowledge (Ford, 2008; NRC, 2012; Klahr & Dunbar, 1988; Rainey et al., 2017).

Questioning or identification of problems stemming from critique rooted in prior knowledge can serve two instructional purposes. These purposes include aiding in the identification of students’ prior conceptions and misconceptions and forming hypotheses to drive student learning (Abd-El-Khalick et al., 2004; Klahr & Dunbar, 1988; NRC, 2012). Educators can capitalize on questioning and underlying curiosity by building what Chi (2009) described as “interactive” (p. 80) approaches to provide opportunities to engage in dialogue, interactions, and manipulations that strengthen student skills.

Beyond the use of student questioning in shaping instruction, instruction may be necessary for providing opportunities to aid students in the construction of questions, including testable questions, and identification of problems consistent with uses by scientists. Klahr and Dunbar (1988) advocated that teaching skills for questioning should not be taught separately from content and practices because such an approach is “highly artificial” (p. 7). As students become increasingly adept at asking scientific questions and identifying problems within the contexts of science, learning of science content can be enhanced through efforts to both construct and critique knowledge and understanding (Ford, 2008; Henderson et al., 2015; Klahr & Dunbar, 1988; Rainey et al., 2017).

The dual role of questioning to construct and critique understanding of science plays a pivotal role in bridging content and practices through literacy. Questions may arise from science
reports in popular media, from textbooks, or from lab data or data sets and drive engagement with content and inquiry to search for and construct science knowledge and solutions to problems (Abd-El-Khalick et al., 2004; Korpan, Bisanz, Bisanz, & Henderson, 1997; Zimmerman, Bisanz, Bisanz, Klein, & Klein, 2001; NRC, 2012; NGSS Lead States, 2013; Roman et al., 2016). Through instruction on the formulation of scientific questions in relation to real world problems or phenomena, students can learn science practices and content in meaningful ways that involve curiosity, critique, and reasoning (Abd-El-Khalick et al., 2004; Ford, 2008; NRC, 2012).

**Modeling.** Modeling is defined by Schwarz et al. (2009) as a core scientific practice that includes processing information to construct knowledge through iterations of evaluation, learning, and revisions. When applying this practice, students benefit from scaffolds or environments that allow access to norms for and uses of modeling in the larger science community (Fredlund et al., 2014; NRC, 2012; Rainey et al., 2017; Schwarz et al., 2009). In utilizing the broad definition of modeling, students can use information that is logically organized to answer a question or address a problem. Models encompass explanations and the variety of methods for showing ideas, concepts, data, and the connections between these components of understanding (Berland & Reiser, 2008; Fredlund et al., 2014). Structures of thinking can be incorporated in models through written, visual, and verbal communications. Engagement in the practice of modeling in the science classroom focuses on students’ internalized models being externalized for review, feedback, and revisions before being re-
internalized as content knowledge (Berland & Reiser, 2008; Chi, 2009; Ford, 2008; NRC, 2012; Schwarz et al., 2009).

Modeling as a scientific process can be constructive, interactive, and predictive. Developing a model of a science concept includes interactions with data collection, data sets, science concepts, and peers (Berland & Reiser, 2008; Chi, 2009; Ford, 2008). The process also involves drawing from prior knowledge coupled with new experiences and learning to organize and connect ideas in the construction of new knowledge. The use of models can serve as an output of understanding as well as a predictive tool that can be used by students to deepen understanding and further learning (Berland & Reiser, 2008; Chi, 2009; NRC, 2012; NGSS Lead States, 2013; Schwarz et al., 2009).

Investigating. In science curricula throughout the world, inquiry skills and processes are an intended focus of instruction (Abd-El-Khalick et al., 2004; Millar & Driver, 1987). Berland and Reiser (2008) presented the use of claims, evidence, and reasoning, which could provide background knowledge necessary for formulating hypotheses and developing investigations for the acquisition of information (Klahr & Dunbar, 1988; NRC, 2012). Students play an active role in the decisions of how to investigate, the required steps for carrying out the investigation, and expected or predicted outcomes. The active role can include social interactions with peers to support investigative practices that parallel the experimental approaches associated with expert scientists, thus aiding in student learning of science (Abd-El-Khalick et al., 2004; Chi, 2009; Ford, 2008; Klahr & Dunbar, 1988; NRC, 2012).

The importance of students assuming an active role in learning was advocated by the research of Chi (2009). Similarly, Ford (2008) recommended that students learn science by acting like scientists. Both positions rely on investigation or inquiry that can provide information
for use in the construction of knowledge. Using evidence and reasoning to justify claims, as presented by Berland and Reiser (2008), can draw from the processes of investigation as long as students have learned and are supported in building and acting on sound practices or experimental designs (NRC, 2012).

**Using data.** Investigations move from hypothesis to experimental design to data collection. The use of data often begins after collection and includes analyses and interpretations (NRC, 2012; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Schwarz et al., 2009; Yager, 2004). Students must learn to use tools to analyze and interpret data for the purpose of sensemaking and knowledge construction (Berland & Reiser, 2008; Norris & Phillips, 2003; Rainey et al., 2017). Student use of analytical and interpretive skills reflects the processes used by scientists to collect and interpret data from experiments (Ford, 2008; NRC, 2012; Rainey et al., 2017). The NRC (2012) recommended looking for patterns in data sets that can be aided by organizing data through visual representations. The analysis and interpretation may be framed as reflections involving reasoning and critique on investigations and resulting data (Berland & Reiser, 2008; Ford, 2008; NRC, 2012; Rainey et al., 2017). Reflecting on data can include evaluation of information that connects ideas or concepts and can contribute to development or revisions of models (Ford, 2008; Osborne et al., 2003; Schwarz et al., 2009).

Experiments, investigations, and research are sources of information. Students must understand the ideas presented in these resources in order to build knowledge and understanding of content (Houseal et al., 2016; Lemke, 2004; Yager, 2004). Yager (2004) viewed this process as science, a means of doing or active engagement and interaction with information, including data. Representing data and looking for patterns can engage students in processes of thinking that
mirror the practices of expert scientists and engages students in active learning (Anders & Guzzetti, 2005; NRC, 2012; Yore, 2004).

**Mathematical thinking.** Mathematics is a tool of communication in what the NRC (2012) termed the “languages of science” (p. 64). Lemke (2004) also viewed mathematics as a means of learning and communicating within the context of science. Numeric and symbolic representations and equations represent data and the relationships between quantities and units of quantities. Using mathematical representations and equations as tools can bolster analysis and interpretation that can be used in the revision of models for both explanatory and predictive purposes. Using mathematical reasoning emerges from experimental investigations, analyses, and interpretations as an application of logic (Berland & Reiser, 2008; Klahr & Dunbar, 1988; NRC, 2012; NGSS Lead States, 2013; Norris & Phillips, 2003; Rainey et al., 2017).

Mathematical thinking in science may appear in the forms of quantities, units, and equations, but it can also be apparent in logical thinking and conclusions generated from analyses of data or other information (Lemke, 2004; NRC, 2012; Yager, 2004). Mathematical thinking is one method for interpreting, interacting with, and understanding science information presented in different forms. This interpretation of information is consistent with using varied forms of text in science (Anderson, 1999; Norris & Phillips, 2003). The use of mathematical perspectives and thinking can support students in constructing science knowledge and claims as well as aid in the communication of these ideas (Yager, 2004; Yore, 2004).

**Explaining.** Student learning can parallel the process of acquiring knowledge in the scientific community, progressing from questioning through analyses and representations in visual and mathematical forms. After analyzing data and reaching conclusions, information must be related back to the original question or driving event and communicated to an interested
audience (NRC, 2012; NGSS Lead States, 2013). Explaining is a process that aids students in synthesizing information that may be obtained from various sources and through various methods to construct and communicate understanding and depends on student attitudes and levels of understanding (Goldman et al., 2016; Pinto & Sales, 2014; Sorvik et al., 2015). Students may present explanations through language, including written and verbal means (NRC, 2012; Yore, 2004).

Arguing from evidence. Similar to the explanation process of understanding information and concepts, arguing from evidence requires forming ideas from the interpretation of data and ideas and communicating this information. However, argumentation differs in the intent of the process. While explanation provides information, argumentation from evidence serves the purposes of defending particular interpretations or positions and persuading others of the validity of the proposed position (Berland & Reiser, 2008; Chin et al., 2016; NRC, 2012). To argue from evidence, students must engage in science practices of analyzing, evaluating, interpreting, and synthesizing information from various sources prior to the formulation and expression of a scientific position or idea. The integration of these practices leads to written or verbal discourse and interactions that engage students in the collaborative, social practices visible in the work of expert scientists (Ford, 2008; Klahr & Dunbar, 1988; NRC, 2012; Yore, 2004).

Gathering, evaluating, and communicating information. Understanding and learning science requires information, but the information used to form accurate, scientifically sound understandings must be reliable and valid (Anders & Guzzetti, 2005; Pelger & Nilsson, 2016). The acquisition of reliable information, especially in science, is a skill to be learned by students that can lead to furthering practices as applied by scientists (Moje, 2015; NRC, 2012; Shanahan & Shanahan, 2015). In this learning, students must learn where to gather information, how to
evaluate the information, and then how to synthesize and communicate the information (Anders & Guzzetti, 2005; NRC, 2012; NGSS Lead States, 2013; Pelger & Nilsson, 2016; Yore, 2004).

The process of acquiring, evaluating, synthesizing, and communicating information relies on previously presented science practices (NRC, 2012; NGSS Lead States, 2013). Questioning can initiate the process that spurs investigation, analysis of data, modeling, logical and mathematical thinking, explanations, arguments based on evidence, and deeper understanding (Berland & Reiser, 2008; Michaels & O’Connor, 2015; NRC, 2012; NGSS Lead States, 2013; Pelger & Nilsson, 2016; Yore, 2004). Scientists cannot rely on information that is presented to them; they must also search for and evaluate information used to form hypotheses and conclusions. As Yore (2004) and Ford (2008) suggested, students can learn science from engaging in these practices.

**Connecting standards and practices through disciplinary literacy.** Although the CCSS and the NGSS are presented with different areas of focus, these sets of standards can be connected through instructional goals and expected practices and outcomes (NGACBP & CCSSO, 2010; NGSS Lead States, 2013). Language and literacy play an important role in the practices of scientists as they process and communicate information and ideas (Yore, 2004). As standards and policies renew a focus on literacy in discipline instruction, connections between literacy instruction and expectations and disciplinary content and practices are relevant in preparing students and providing opportunities to engage in learning as scientists (NGACBP & CCSSO, 2010; NGSS Lead States, 2013). These connections can include the development of higher order thinking skills as well as science and literacy practices (Anders & Guzzetti, 2005; Moje, 2008; Shanahan & Shanahan, 2008; Yager, 2004; Yore, 2004).
Higher order thinking skills. The CCSS and the NGSS stressed the importance of higher order thinking skills and the ability to communicate information through varied forms (NGACBP & CCSSO, 2010; NGSS Lead States, 2013). Science instruction centered on phenomena or real-world situations and questions can facilitate the use of higher order thinking skills through practices authentic to the discipline and inclusive of disciplinary literacy and the use of multiple perspectives to reach consensus (Bennett & Hart, 2014; Fang & Coatoam, 2013; NGSS Lead States, 2013; Pelger & Nilsson, 2016; Prinsloo, 2018). The use of higher order thinking skills developed through features of disciplinary literacy is identified in the work of Goldman et al. (2016), which included the investigation of evidence-based knowledge, inquiry, reasoning, concepts, representations of information and types of text, and disciplinary discourse and language. Features of disciplinary literacy and science instruction align with the NGSS identified practices of questioning, modeling, analyzing and interpreting data, explaining, argumentation using evidence, and gathering, evaluating, and communicating information (Goldman et al., 2016; NGSS Lead States, 2013). Science instruction aligned with desired outcomes as presented in standards support embedded disciplinary literacy practices in science instruction in authentic and meaningful ways (Fang & Coatoam, 2013; Goldman et al., 2016; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015).

Science practices in literacy. The eight science practices enumerated by the NRC (2012) are themes that attempt to summarize the behaviors exhibited by scientists and therefore represent areas in which uses of literacy by scientists may be embedded (Houseal et al., 2016; McConachie, 2010; Zygouris-Coe, 2012). Identified components of literacy can be integrated into the use of science practices in ways that are meaningful to the science discipline and authentic to the behaviors of scientists (McConachie, 2010; Moje, 2008; NGACBP & CCSSO,
The combining of literacy and science practices creates a conduit for providing students with opportunities for constructing science knowledge (Goldman et al., 2016; Houseal et al., 2016; McConachie & Petrosky, 2010).

**Science practices and reading.** Reading in science should not be focused on typical reading instruction of decoding and comprehension but should focus on understanding different forms of text through the application of reasoning and logic (Yager, 2004). When assuming this approach advocated by Yager (2004), the process of using text to construct knowledge presented in the work of McConachie (2010) can be viewed through the science practices of analyzing and explaining. Students must analyze and bring together information from diverse texts to synthesize and explain science concepts. The practice of explaining goes beyond the simplistic statement of a definition and is a cyclical process of sensemaking from texts requiring logical and possibly mathematical thinking (Kuhn & Reiser, 2005; McNeill & Krajcik, 2006; Spiegel, Bintz, Taylor, Landes, & Jordan, 2010).

An expanded definition of text in science to include writing, visual representations, data, and equations requires expanding the concept of reading from the traditional meaning construction of written text (Lemke, 2004; Yager, 2004). This view can aid in addressing the issue of text complexity in textbooks by varying the methods used in learning vocabulary (Snow, 2010; Zmach et al., 2006). The use of science practices allows for questioning and investigation that provide context for reading and analyzing data, diagrams, and traditional written texts. Through iterative reading, analysis, and interpretation, students can engage with and construct an understanding of science concepts (McClune & Jarman, 2010; Spiegel et al., 2010).

Rupley (2010) advocated connecting hands-on investigation with literacy practices, specifically reading. Instruction that incorporates reading about science does not adequately
engage students with science practices (Enfield, 2014; Rupley, 2010; Yager, 2004). Concurrent use of reading and inquiry may also reflect the use of science practices as students read, develop, and follow multistep procedures to prepare for and carry out investigations. Reading can also be applied at the conclusion of inquiry investigations as students read, analyze, and interpret data (Rupley, 2010).

Fundamental literacy as described by Norris and Phillips (2003) and applied by Enfield (2014) uses reading as one piece of instruction that drives the use of science practices leading to building conceptual knowledge. Reading can be integrated into the practices of questioning, investigating, analyzing, explaining, and arguing from evidence (Michaels & O’Connor, 2015; Rupley, 2010). This integration moves beyond traditional written texts to be more inclusive of the diverse texts of the science discipline (Lemke, 2004; NRC, 2012; Spiegel et al., 2010; Yager, 2004). Reading as a fundamental component of science can result in practices that build knowledge (Enfield, 2014; Norris & Phillips, 2003).

Science practices and writing. Writing in science can be viewed as a constructive practice that aids in the generation of knowledge (Klein & Unsworth, 2014; Yore, Hand, & Prain, 1999, 2002). When viewed in the context of science practices, knowledge generation through writing can occur as a product of communication, explanation, and feedback. Writing can be a method of synthesizing information derived from questioning, investigating, and analyzing. Explaining and arguing from evidence can also be presented in writing (Florence & Yore, 2004; Hand, Norton-Meier, Gunel, & Akkus, 2015; Pelger & Nilsson, 2016; NRC, 2012; Yore, Hand, & Florence, 2004; Yore et al., 1999, 2002).

Writing in science may be manifested as written laboratory reports with the narrow focus of summarizing learning and presenting conclusions (Yore et al., 2002). While these reports are
focused on particular experiences, they include explanations of data and supporting analyses of
the data. Writing in science can include reports and other forms of writing that draw multiple
learning experiences. Yore et al. (1999, 2002) presented writing in science as a process that
transforms and constructs knowledge through synthesis of these learning experiences, which can
result from engagement in science practices (Florence & Yore, 2004; Klein & Unsworth, 2014;
Yore, 2000; Yore et al., 1999, 2002).

The use of writing to synthesize ideas can be demonstrated in modeling science concepts.
These models based on writing can compare data, observations, and information from a variety
of sources. The inclusion of analysis and identification of patterns consistent with the use of
science practices can be expressed in writing and modeling and allow for predictions based on
students’ current levels of understanding of science concepts (Klein & Kirkpatrick, 2010).
Modeling and the use of information is consistent with science practices outlined by the NRC
(2012).

Writing is also a form of communication that can aid in the collaborative, social
processes of science. Interactions between scientists can be facilitated through writing and
initiate a discourse between peers (Drew et al., 2017; Hand et al., 2015; Klein & Unsworth,
2014). The social nature of writing can be developed through the science practices of explanation
and arguing from evidence (Klein & Unsworth, 2014; Yore, 2000; Yore et al., 2004). As
reasoning is made public through writing, students can engage as scientists to understand
concepts (Drew et al., 2017; Hand et al., 2015; Klein & Unsworth, 2014).

Writing is a process that allows students to access scientific information and gain entry to
the scientific community. Through writing, students can better understand how to create and
share science content knowledge, a process integral to science practices (Klein & Unsworth,
Through use of writing embedded in science practices, students can progress from the use of writing as telling to the use of writing to transform and construct knowledge (Yore et al., 2002). The use of writing reflects science communication and social interactions as practiced by expert scientists. Writing can be used to identify patterns and present arguments that form explanations and connections between practices and content (Hand et al., 2015; Klein & Kirkpatrick, 2010; Klein & Unsworth, 2014; Yore et al., 1999, 2002).

Science practices and speaking and listening. Speaking and listening can be viewed as a component of scientific discourse centered on communicating and constructing science knowledge. Discourse focuses on eliciting and making public student thinking to create a deeper understanding of content (Remedius, Clarke, & Hawthorne, 2008; Spiegel et al., 2010). Educators can assist this process by structuring classroom instruction based on protocols and questioning that foster student discourse with each other using content. Students can become accustomed to sharing thinking, responding to thinking, and constructing knowledge based on evidence and thinking presented through discourse (Michaels & O’Connor, 2015; Michaels et al., 2008; Remedius et al., 2008; Spiegel et al., 2010; van der Veen et al., 2015).

Discourse aligns with the social aspects of science practices and may be used as a method of explanation and argumentation from evidence (Chin et al., 2016; Berland & Reiser, 2008; Michaels et al., 2008; Spiegel et al., 2010). Students are able to engage in providing and receiving feedback to and from peers regarding science concepts. Using data derived from investigations and analyses to support argumentation and explanations can draw science practices into the use of discourse and the construction of science knowledge (Chin et al., 2016; Berland & Reiser, 2008; Michaels & O’Connor, 2015; Michaels et al., 2008; Remedius et al.,
Summary of science practices and literacy. When practices and literacy are integrated into science instruction, students can learn about and engage in behaviors that are similar to those used by expert scientists. Critical thinking skills can be developed as students investigate, apply reasoning, mathematical and logical thinking, and engage in discourse to construct knowledge and understanding of science concepts (Hand et al., 2015; Houseal et al., 2016; NRC, 2012). Literacy skills can be integrated into science practices to promote the behaviors of scientists in ways that expose students to and engage students in these behaviors, resulting in learning and application of science concepts (Hand et al., 2015; Houseal et al., 2016; Lent, 2015; Rupley, 2010; Spiegel et al., 2010; van der Veen et al., 2016; Yore, 2004).

Critiques of Disciplinary Literacy Instruction in Science

Disciplinary literacy is presented as an authentic approach to incorporating tasks and skills used within a discipline through methods that provide context and meaning for student learning and application of skills (Goldman et al., 2016; Shanahan & Shanahan, 2008). The implementation of literacy skills through instruction that fits with authentic uses of literacy in the discipline is promoted as positively impacting student engagement and achievement from upper elementary grades through secondary and post-secondary educational experiences (Fang & Coatoam, 2013; Shanahan & Shanahan, 2008). In contrast to the positive outcomes presented by Shanahan and Shanahan (2008), Faggella-Luby et al. (2012) raised concern that a complete shift in literacy instruction would neglect skill development found in content area literacy approaches. This concern encompassed the view that without skill development, students would not be able
to engage with disciplinary literacy and science practices (Faggella-Luby et al., 2012; Fisher & Ivey, 2005).

The lack of transferability or difficulty in transferring skills outside of the content area in which learning occurs is identified as a weakness of disciplinary literacy instruction (Faggella-Luby et al., 2012). Learning of literacy skills as a component of disciplinary learning can result in skills that are compartmentalized to a specific domain or to specific content within a discipline. The effectiveness and usefulness of instruction to improve student achievement is limited by the lack of student ability in generalizing the use of literacy skills (Faggella-Luby et al., 2012).

The inability to transfer skills beyond a concept or discipline result in frustration for both educators and students. Learning of literacy skills that cannot or are not transferred may be viewed as unworthy of the invested time, thus stifling potential for improving reading and writing skills that can benefit content learning across disciplines (Faggella-Luby et al., 2012; Fang, 2012). Fisher and Ivey (2005) identified educator frustration or resistance as key to the lack of achievement in content area literacy models. Similarly, this frustration of educators and students can undermine the overall importance of literacy skills within and beyond disciplinary contexts (Drew & Thomas, 2018; Faggella-Luby et al., 2012; Fang, 2012; Fisher & Ivey, 2005). As Fisher and Ivey (2005) presented, student literacy skills can be limited due to the implementation of various types of literacy instruction.

Furthermore, the frustration of learning literacy skills can be exacerbated for struggling learners due to the lack of scaffolding specific skills. Instruction of literacy embedded within discipline content instruction may not be clear to learners that are impaired by developmental disabilities or medical conditions. Learners that require differentiated supports for learning may
require content area literacy instruction on skills that provide context and meaning of skills as related to discipline content and the transfer of skills to varied contexts (Faggella-Luby et al., 2012). Content area literacy instruction may benefit certain students in developing necessary skills (Faggella-Luby et al., 2012).

In addition to weaknesses of disciplinary literacy, Faggella-Luby et al. (2012) identified a lack of supporting research for the effectiveness of disciplinary literacy as a literacy model. The lack of research supporting disciplinary literacy causes concern for wholesale shifts to disciplinary literacy instruction and the abandonment of content area literacy strategies. While the body of literature supporting disciplinary literacy is continuing to grow (Fang, 2014, 2012; Fang & Coatoam, 2013; Ingram et al., 2016; Tang, 2016), Brozo et al. (2013), Moje (2015), and Shanahan and Shanahan (2008, 2015) recognize the need for research, development, and refinement of literacy instructional models, including the model of disciplinary literacy.

Brozo et al. (2013) pointed to the dichotomy between content area literacy and disciplinary literacy as cause for concern. Pursuing literacy instruction on either extreme of disciplinary or content area literacy is presented as inadequate for meeting the needs of all learners (Brozo et al., 2013; Faggella-Luby et al., 2012). Brozo et al. (2013) suggested research and establishment of methods that involved mediating the different perspectives to provide a means of literacy instruction that is amenable to the needs of students and educators both within a discipline and across disciplines. While Shanahan and Shanahan (2008) advocated a disciplinary literacy approach, the focus was on the need for teaching literacy skills and therefore ideas of Brozo et al. (2013) and Ingram et al. (2016) may be incorporated into a modified disciplinary literacy approach that addresses the weaknesses of content area literacy and disciplinary literacy and accounts for the needs identified by Faggella-Luby et al. (2012).
Educator Role in Disciplinary Literacy

As Norris and Phillips (2003) proposed, the idea of literacy in disciplines was identified as necessary for content learning. While standards were developed that supported this position, implementation of instruction consistent with recommendations is varied at best, with educator attitudes and adoption of pedagogy being directly linked to the efficacy of literacy instruction (Drew & Thomas, 2018; Fisher & Ivey, 2005; Norris & Phillips, 2003; Osborne et al., 2003). The development and implementation of new standards must be supported with appropriate pedagogy to reach the desired levels of achievement, which includes literacy instruction in disciplinary courses, such as science courses. Literacy instruction in science has evolved over time to meet both literacy and content needs of students. Two movements in the United States, the CCSS and the NGSS, have brought literacy and content approaches to the forefront of science instruction, thus requiring shifts or adaptations in pedagogy to facilitate opportunities for student learning and advancement throughout their lifetimes (Fang & Coatoam, 2013; Fisher & Ivey, 2005; Moje, 2008, 2015; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Shanahan & Shanahan, 2008, 2015; Zygouris-Coe, 2012).

Fisher and Ivey (2005) presented educators as key in transforming intent of standards into practices and opportunities that allow for student learning and achievement. Educator perceptions and approaches can impact the success of disciplinary literacy instruction (Brozo et al., 2013; Fang et al., 2014; Fisher & Ivey, 2005). Research on educator relationship to disciplinary literacy has focused on two groups of educators, preservice and in-service.

Preservice teacher perceptions. By definition, preservice teachers lack experience in the classroom and therefore lack experience with organizational and procedural perspectives. The lack of experience can influence views on literacy instruction in disciplinary courses. Due to lack
of experience, preservice teacher perceptions of literacy may range from supportive of the practice based on exposure during training to an approach that is absent of value for the practice. Preservice teachers require clarification of value and pedagogical knowledge for the implementation of disciplinary literacy instruction (Bennett & Hart, 2014; Carlson, 2015; Colwell & Enderson, 2016; Hart & Bennett, 2013; Masuda, 2014; Orr & Kukner, 2015).

Instruction in disciplinary literacy for preservice teachers can aid in improving understanding of disciplinary literacy, but preservice educators have been found to have difficulty in transferring this understanding to practice once classroom teaching begins (Carlson, 2015; Bennett & Hart, 2014; Hart & Bennett, 2013; Masuda, 2014). McArthur (2012) analyzed the use of a metalinguistic protocol to determine quality of disciplinary literacy instruction implementation and determined the complexity of disciplinary texts and textual relationships are areas of struggle for novice or beginning educators. Additionally, beginning educators may struggle to align disciplinary literacy instruction with developmental needs of students (McArthur, 2012). To overcome the lack of confidence and limited transfer of preservice educator implementation of disciplinary literacy instruction, Colwell and Enderson (2016) recommended training focused on improving and clarifying the complexities associated with transitions from general strategies to disciplinary literacy instruction. This existing research demonstrated a focus on the preparation of preservice educators for disciplinary literacy instruction as implemented in the science classroom. Therefore, additional research on how in-service educators apply disciplinary literacy instruction is necessary.

In-service teacher perceptions. In-service educators value new approaches and are willing to learn and implement disciplinary literacy instruction (Fang et al., 2014; Stasinakis & Athanasiou, 2016). This shift in instruction, while aided by willing attitudes of educators,
required support for professional learning opportunities and the transfer of learning to practice as outlined by Roseler and Dentzau (2013) and Zhang et al. (2015). Supports for educator implementation of disciplinary literacy may vary depending on the structure of different educational systems. Collaborative relationships can increase support for transitions to disciplinary literacy and may include instructional literacy coaches as long as collegial relationships can be established (DiDomenico, Elish-Piper, Manderino, & L’Allier, 2017; Fang, 2014; Hansen et al., 2016; Wilder, 2014).

Strategies implemented by in-service educators are typically chosen based on the relevancy of strategies to the disciplines or concepts of the discipline being taught (Drew & Thomas, 2018; Fisher & Frey, 2008). Educators are also focused on strategies that foster higher order thinking skills and the application of these skills within content-based learning opportunities (Rozenszajn & Yarden, 2014; Wolsey, Lapp, & Fisher, 2012). Educators can consider relevancy of skills, including literacy and higher order thinking skills, by drawing from the strategies and components of literacy visible in the work of disciplinary experts. Planning based on identified skills can be reflective of educator practice that includes the influences of curricula, pedagogy, content, and culture (O’Brien et al., 1995). Instruction based on the skills exhibited by disciplinary experts can be used to create classroom communities that address literacy needs in contexts that mirror authentic, discipline-specific contexts (Goldman et al., 2016; McArthur, 2012).

In-service educators have experience functioning within institutional structures. Contrasting to the inexperience of preservice educators that do not fully grasp institutional procedures and policies, in-service educators may feel confined by directives from administrators or expectations of curricula. Additionally, deadlines, pacing of instruction, and other school-wide
initiatives can limit in-service educator latitude for implementation of new practices and lower educator efficacy (Brozo et al., 2013; Hannant & Jetnikoff, 2015; Masuda, 2014). Social and cultural aspects of education and educational systems can either assist or limit educator ability to learn about and effectively implement literacy instruction within discipline instruction (Hannant & Jetnikoff, 2015; O'Brien et al., 1995).

**Theoretical Framework**

Educator attitudes and actions are reported as influential in the efficacy of disciplinary literacy instruction (DiDomenico et al., 2017; Drew & Thomas, 2018; Fisher & Ivey, 2005; Norris & Phillips, 2003; Osborne et al., 2003; Spiegel et al., 2010). As proposed by Spiegel et al. (2010), educators must be aware of both science and literacy content and instruction. The confluence of content and pedagogical knowledge can be considered through the application of Shulman’s (1986, 1987) theory of PCK. Shulman (1986, 1987) developed this theory in response to varied emphases on content and pedagogy throughout the history of education and teacher certification requirements in the United States. The theory of PCK demonstrated the interaction of content and pedagogy as a means for transforming knowledge into forms understandable by students. The resulting theory of interrelated components of content and pedagogy became known as PCK (Shulman, 1986, 1987).

**Shulman's theory of PCK.** Teaching and learning rely on content and practices integrated through pedagogy that reflects an understanding of content knowledge. Whether focused on science content, literacy content, or the combination within disciplinary literacy, educator practices must act on pedagogy and content knowledge. Shulman (1986) noted that throughout history, the emphasis on educator credentials has shifted back and forth between being content experts and pedagogical experts. Shulman (1986) noted that each extreme, whether
content or pedagogy centered, neglected the other and therefore compromised impactful instruction. To explain the need for integrating pedagogy and content knowledge in considerations of instruction, Shulman (1986, 1987) developed the theory of PCK.

In establishing the theory of PCK, Shulman (1986, 1987) investigated preservice educators, novice educators, and experienced expert educators. Shulman (1986, 1987) determined through observations, interviews, and case studies the processes and abilities of educators to transform content knowledge through reasoning and pedagogy into understandable units for learners. The process of developing and using PCK relies on various factors that include time and experience with content and pedagogy, professional development and training of educators, educator background and attitudes, and systems of educator evaluation (Shulman, 1983, 1986, 1987). The development of the theory also focused on bringing together the constructs of content and pedagogy identified by Shulman (1986, 1987). Rather than shifting between content and pedagogy, Shulman (1986, 1987) worked to describe the interactions of these components in impactful instruction.

Shulman (1983) viewed the shifts in approaches to education toward and away from content and pedagogy as the result of behaviors driven by values and fears, which are visible in science teacher resistance and attitudes toward literacy instruction in the content area (Drew & Thomas, 2018; Fisher & Ivey, 2005). Attitudes of science educators may be driven by fear that content area literacy approaches neglect content instruction in favor of generalized literacy instruction and therefore represent policies that set unattainable expectations for content and literacy education (Fisher & Ivey, 2005; Shulman, 1983). Actions to improve schools or create meaningful change in educational systems rely on bringing together policy, research, and pedagogy, which may be applied to adaptations or shifts in literacy instruction as applied to each
discipline (Moje, 2008; Shanahan & Shanahan, 2008; Shulman, 1970, 1974, 1983; Spiegel et al., 2010).

Shulman's (1986, 1987) re-emphasis of content knowledge applied to literacy instruction did not diminish the importance of science content knowledge in instructional approaches. Literacy skills represented methods for engaging with science content (Spiegel et al., 2010). Similarly, shifts in science instruction to include science practices relied on knowledge of content and practices used by scientists. Science knowing and doing through the use of literacy skills and science practices were connected to educational theory that includes "understanding" and "doing" (Bruner, 1960, p. 29) as methods of constructing knowledge (NRC, 2012; NGSS Lead States, 2013). The combination of knowing and doing in science incorporated Dewey's (1904, 1911) idea of moving beyond the learning of individual facts to the facilitation of understanding and the application of ideas that allow for the construction of knowledge. Science practices can be viewed as essential teaching processes that include active and interactive learning processes that elicit and construct knowledge through collaborative interactions that are authentic to the use of these processes in science (Shulman, 1989). Educator implementation of PCK is responsive to the context of instruction and can be adapted to fit the needs of learners and disciplinary content and skills, such as the use of science practices to integrate literacy in content learning (Goldman et al., 2016; Houseal et al., 2016; Shulman, 1970, 1983, 1986).

While teacher preparation and evaluation have traditionally treated content and pedagogy as a dichotomy, content knowledge and pedagogical knowledge both play a role in teaching. Shulman (1986, 1987) proposed that successful educators possess a balance and interaction of content knowledge and pedagogical knowledge that enhance the teaching and learning process. Shulman (1987) outlined categories of teacher knowledge that include disciplinary content,
general pedagogy, pedagogical content and curricular. The structure of knowledge presented by Shulman (1986, 1987) is significant in the assertion that educator preparation and evaluation should be based on a symbiosis of content and pedagogy termed "pedagogical content knowledge" (PCK; Shulman, 1986, p. 9). In PCK, general pedagogy is re-interpreted to meet the needs of specific content instruction, which is true in the considerations of science instruction, literacy instruction, and disciplinary literacy instruction (Goldman et al., 2016; Shulman, 1987).

Classroom instruction relies on a balance of educator knowledge of content and practice of skills or pedagogy that creates an environment where students can understand and engage in experiences that transform information and provide opportunities for learning (Shulman, 1986, 1987). In the case of disciplinary literacy instruction, educators must have knowledge in pedagogy and content for science, literacy, and the interactions of science and literacy. Links between specific content topics and pedagogical strategies for teaching the content were identified by Shulman (1987). Shulman's (1986) theory of PCK can be applied to disciplinary literacy to explain the overlap of content and pedagogical knowledge of both science and literacy.

**Constructs of PCK.** In the theory of PCK, researchers recognized the importance of context and the overall educational goals or outcomes (Grossman, 1990; Shulman, 1986, 1987). To meet established educational expectations, PCK was constructed on the knowledge of individual educators. Shulman (1986, 1987) stressed that content knowledge is essential for teaching, but content relied on pedagogy for the creation of learning experiences. The theory of PCK was supported by the individual constructs of content knowledge and pedagogical knowledge merging or influencing beliefs and practices of the educator (Grossman, 1990;
Magnusson et al., 1999; Shulman, 1986, 1987). The resulting construct of PCK supported learning specific to the educator, student, and content of instruction (Grossman, 1990).

Content knowledge. Content knowledge consists of the factual information, concepts, and understanding required within a discipline (Shulman, 1986, 1987). Grossman (1990) included beliefs and subject matter as components of content knowledge. Interactions of knowledge and beliefs about subject matter within an academic discipline formed the basis of content knowledge (Magnusson et al., 1999). Shulman (1987, 1989) placed learning of content as an essential part of educator preparation, often requiring a deeper content knowledge to teach the subject matter than to use the knowledge in other professions or contexts.

The work of Schwab (1964, 1983) was influential in Shulman's (1987) construct of content knowledge. Substantive knowledge consisting of concepts and principles within a discipline formed one branch of content knowledge (Grossman, 1990; Magnusson et al., 1999; Schwab, 1964, 1983; Shulman, 1987, 1989). Concepts and principles of a discipline can be learned, often through coursework within disciplinary departments outside of colleges of education (Shulman, 1983, 2004). Substantive content knowledge was reflected in the amount and understanding of disciplinary ideas, concepts, and facts maintained by the educator (Grossman, 1990; Magnusson et al., 1999; Schwab, 1964; Shulman, 1986). Knowing information as represented in substantive knowledge is important in providing the basis for continued learning and inquiry (Shulman, 1987).

Knowing the facts of a discipline only constituted half of the content knowledge construct (Grossman, 1990; Shulman, 1987). In addition to substantive knowledge, Shulman (1986, 1987) again drew from Schwab (1964, 1983) to include syntactic knowledge. Enquiry can be used to create a deep understanding of content principles in the mind of the teacher to
establish the validity of concepts in a discipline (Shulman, 2004). Syntactic content knowledge served to aid the educator in organizing content information. Understanding disciplinary processes, procedures, and information allows the educator to move beyond recall of factual content to a thorough comprehension of structures of content knowledge (Shulman, 2004).

In policy and research topics, content knowledge may be overlooked and resulted in Shulman (1986) labeling subject matter content knowledge the "missing paradigm" (p. 7). Even though content knowledge inclusion in policy and research varies, content is essential in teaching. A knowledge of the subject matter being taught is essential in planning instruction (Shulman, 1986, 1987). Shulman's (1986, 1987) theory re-emphasized the importance of content knowledge in shaping instruction and facilitating learning opportunities for students and advocated the inclusion of content perspectives in policy and research.

The inclusion of content knowledge in research and policy can further understanding on effective practices of teaching (Shulman, 1986, 1987). Research designed with a content focus can provide insight into what educators are required to know and understand in order to teach (Shulman, 1987, 2004). Furthermore, research on content knowledge can elaborate complexities of and key practices in learning in specific disciplines (Shulman, 1998). The amounts of content information necessary, the substantive knowledge, and the procedures for establishing content, the syntactic knowledge are areas of focus in research on content knowledge (Schwab, 1964, 1983; Shulman, 1987). Content knowledge research is supported by Shulman's (1986, 1987) theory as a contributor to the formulation of PCK.

**General pedagogical knowledge.** General pedagogical knowledge is a second construct within Shulman's (1986, 1987) theory of PCK. Shulman (1986) documented an increase in the reliance of educational communities on the skills necessary to organize learning environments
and facilitate learning opportunities. One prevailing attitude identified by Shulman (1987) placed pedagogical skill as more important than content knowledge. In this view, what was being taught was of less importance than the choices for how to form instruction. In the evaluations of teachers, knowing how to teach was given priority over knowing the content to be taught (Shulman, 1986, 1987).

Magnusson et al. (1999) identified "classroom management, instructional principles, learners and learning, and educational aims" (p. 98) as factors that contribute to general pedagogical knowledge. Classroom management consisted of establishing expectations, creating the learning environment, and fostering student behaviors conducive to learning (Magnusson et al., 1999). Educator knowledge and beliefs can be expressed in the norms established within the classroom. Moral and ethical positions are also manifested through educator relationships and actions (Shulman, 1986). The learning environment is one factor based on educator beliefs and knowledge contributing to pedagogical knowledge (Magnusson et al., 1999; Shulman, 1987).

Shulman (1986, 1987) advocated varied instructional strategies and cautioned against viewing the educator as a deliverer of facts and information. Active learning through experiences consistent with the instructional theories of Bruner or Dewey informed pedagogical knowledge (Shulman, 1974, 1987, 1989, 2004). Instructional principles that inform pedagogical knowledge should be selected based on needs and anticipated outcomes and can range from lecture to active approaches such as problem-based learning (Shulman, 2004). Varied instructional strategies can be applied to create environments that provide learning opportunities for students (Shulman, 1970).

Instructional principles and learning environments need to respond to learning attributes and needs as well as expected outcomes. Shulman (1970, 1974) included learner characteristics
as contributors to decisions within the pedagogical knowledge construct. Understanding the prior knowledge and experiences of students informs teacher selection of instructional approach and the organization of the learning environment (Shulman, 1970). Educational goals or outcomes are also considerations that guides decision making in pedagogical knowledge. The selection of objectives can align with characteristics of learners and educational goals (Shulman, 1970).

Research provides the basis for knowledge on teaching (Shulman, 1986, 1987). Exploration of characteristics of learners and environments can aid educator reasoning and decision making in regards to pedagogy. Educator ability to choose pedagogy relies on an understanding of learners, environments, and expectations and on a body of instructional and management philosophies and theories supported by research (Shulman, 1970, 1986, 1987). This ability of educators to understand and choose pedagogy followed from research-based practices (Shulman, 1970, 1986, 1987).

*Pedagogical content knowledge.* Critical to the theory of PCK was Shulman's (1986, 1987) conceptualization of a construct that united content knowledge and pedagogical knowledge. Pedagogical content knowledge represented an awareness of the transformative interactions between what the educator knows and how the educator relates specific content to a group of learners (Shulman, 1986, 1987). Educators take content knowledge of a discipline topic and align what is to be taught with an appropriate pedagogy. The processes of recalling information and reasoning through pedagogical options often occurs within the mind of the educator and can reach the point of being subconsciously completed by expert or veteran educators (Hutchings & Shulman, 1999; Shulman, 1987, 1998).

Pedagogical content knowledge is a construct that contributes to the teaching and learning processes from planning through evaluation. Shulman (1987) described a cyclical
process of "pedagogical reasoning and action" (p. 15) involved in PCK. Pedagogical content knowledge begins with an understanding of subject matter and disciplinary concepts and ideas. This understanding is then transformed by the educator through planning and preparation that selects pertinent information and adapts the content through varied interpretations and representations based on student needs and characteristics. After content has been transformed, instructional principles are selected and implemented to facilitate learning opportunities for students. Learning can be evaluated through formative and summative methods and the educator can reflect on processes and outcomes. The cyclical nature of planning, instruction, evaluation, and reflection produces new and deeper understanding of both content and pedagogy (Shulman, 1987).


Research can explore the relationships between pedagogy and content traditionally held in the minds of expert educators. Processes of preparation and transformation are often unobservable. Due to the invisible nature of mental processes, attention is commonly focused on the visible and measurable characteristics of teaching and learning, such as instructional strategies and student achievement measures (Shulman, 1983, 1986, 1987). While these measures may not offer a quantitative measure of mental processes, insight can be gained by

Researchers can analyze the components of PCK through case studies and investigations that bring the hidden processes that occur in the minds of expert educators into public view (Hutchings & Shulman, 1999; Shulman, 1986, 1987, 1998).

Other supporting constructs. Shulman (1986, 1987) proposed PCK to merge pedagogy and content in support of instruction that leads to learning. Learning in educational systems is often organized by curriculum, thus requiring curricular knowledge when setting educational objectives and planning instruction aligned with meeting objectives (Grossman, 1990; Shulman, 1986, 1987). Shulman's (1986) discussion of curriculum extended to the full complement of programs available for teaching selected content. When considering curricular knowledge as the full range of available programs, an educator needs to understand the access to programs and the relationship between the program, content, and pedagogy (Shulman, 1986).

An educator should also have knowledge of the students to be taught. This knowledge includes characteristics of individual learners and of groups of learners (Shulman, 1986, 1987). Teachers should understand the characteristics of what learners know and are able to do prior to entering the classroom or learning environment. Knowledge of learners may be specific to individuals, including interests, abilities, and aptitudes, or the knowledge of learners may be broadened to encompass common or historical misconceptions of disciplinary topics and concepts (Grossman, 1990; Shulman, 1970, 1974, 1987). Knowledge of learners can aid in the selection of content, pedagogy, and curricular program to benefit the learner or group of learners (Shulman, 1987).

The educator needs to be aware of the contexts in which meaningful learning occurs. Context can extend from interactions within a classroom environment to the overarching
governance of schools, districts, and departments of education (Shulman, 1987). Financial contexts can impact resources available to educators (Shulman, 1986). Norms and expectations established in classrooms and schools create a culture that influences content and pedagogical decisions (Shulman, 1986). An expert educator understands community and classroom contexts and can choose pedagogy that meaningfully transforms content for students within these contexts.

Educational decisions also need to be made with consideration of the purposes of teaching the content. Purposes may include underlying values and philosophies related to the prioritizing of what to teach and how to teach (Shulman, 1986). Content and pedagogical decisions can be anchored in historical contexts of a community, but can change as understanding of contexts, learners, and educational systems continually evolve (Shulman, 1986, 1987). Educators must be aware of and understand the expected goals and outcomes of instruction (Shulman, 1986, 1987). Changes in pedagogy and content serve to meet the desired ends of education as established by institutions and systems (Shulman, 1987).

Shulman’s (1986, 1987) theory of PCK considered varied components of teaching and learning within the overall institutions and systems of education. Conscious and subconscious decisions about pedagogy and content made by educators are influenced by curricula, characteristics of learners, context, and the purposes of education. The confluence of factors shapes the resulting environments and opportunities for learning. As educators continue to reflect on experiences, each factor will be impacted resulting in an evolving PCK (Shulman, 1986, 1987). An evolving PCK will reflect the varied components within the classroom and of the larger systems governing the classroom (Shulman, 1986, 1987).
Interrelationships of constructs. The constructs of content knowledge and pedagogical knowledge interact to form the central construct of PCK (Shulman, 1986, 1987). Within the theory of PCK, Shulman (1986, 1987) identified additional forms of knowledge that support pedagogical and content reasoning. Propositional, case, and strategic knowledge forms aid the educator in both developing knowledge and shaping practice through the interaction of content and pedagogy (Shulman, 1986). The interaction of propositional, case, and strategic knowledge coupled with interactions of content and pedagogy influence the construction of PCK that is expressed through instructional decisions of teachers (Shulman, 1986, 1987).

Interactions in the formation of PCK. The constructs of pedagogical knowledge and content knowledge may be treated as distinct constructs, but PCK draws from each construct to transform content through pedagogy (Grossman, 1990; Magnusson et al., 1999; Shulman, 1986, 1987). PCK relies on the educator's deep content knowledge. Superficial understanding of disciplinary content limits the ability of the educator to select relevant content and represent that content in a manner meaningful to students (Shulman, 1983, 1986, 1987). Educators with an understanding of structures within a discipline are better prepared to select pedagogy that can be used to facilitate learning opportunities. However, educators need to be knowledgeable of different philosophies and pedagogies to select pedagogy aligned with content. Without a diverse and comprehensive knowledge of pedagogy, options for transforming content will be limited (Shulman, 1983, 1986, 1987).

Pedagogical reasoning described by Shulman (1987) included instruction and reflection to enhance educator knowledge of both content and pedagogy. As the educator understands how content and pedagogy impact the experience of the learner, adjustments to content, pedagogy, or both can result in a new comprehension of educational content and purpose (Shulman, 1987).
The complexities of educational programs can be reconsidered as comprehension is viewed through the interactions of pedagogical and content choices. Pedagogical content knowledge moves educational decisions from a focus on individual variables, such as content or pedagogy, to processes and outcomes in totality (Shulman, 1983, 1987). Interactions of content knowledge and pedagogical knowledge form PCK, which educators can use to establish learning opportunities and promote student achievement (Shulman, 1983).

Grossman (1990) viewed PCK as a central component resulting from influences of content, pedagogy, and context. Magnusson et al. (1999) applied this conception of PCK to science education. PCK is presented as an organizing construct for teaching science through decisions about curricula, student understanding, instruction, and assessment. Each of these four areas is impacted by knowledge of content and pedagogy. Initially, curricula can aid in determining the aims of science learning, which dictates the content knowledge required by the educator (Magnusson et al., 1999).

After establishing levels and topics of content knowledge of the educator, the characteristics of learners, including prior knowledge and experiences of learners and common misconceptions of learners can be considered by the educator (Magnusson et al., 1999). Transformation and interpretation of content to levels appropriate to the learners influence the pedagogy choices (Magnusson et al., 1999; Shulman, 1986). Pedagogical decisions are presented to students through the expressed instructional philosophies and strategies implemented in learning opportunities. General and discipline specific pedagogies may be combined to express content in PCK (Magnusson et al., 1999).

Finally, science PCK both influences and is influenced by assessment (Magnusson et al., 1999). Formative and summative assessments are a component of instructional pedagogy that
monitor student learning (Shulman, 1987). Additionally, information resulting from assessments can also be used by the educator to revise levels of content and presentation of content. Assessments provide feedback that can be used to other pedagogy, content, or the interaction of the constructs (Magnusson et al., 1999; Shulman, 1987).

As described by Grossman (1990) and illustrated by Magnusson et al. (1999) in science instruction, the constructs of pedagogical and content knowledge interact within the construct of PCK. The interactions of content and pedagogy represent a process that models the reasoning and actions of educators (Shulman, 1986, 1987). Shulman (1986, 1987) presented this process as incomplete when either pedagogy or content is de-emphasized or ignored.

*Interrelationships of supporting forms of knowledge.* The categories of content knowledge, general pedagogical knowledge, PCK, and curricular knowledge are supported through "propositional, case, and strategic forms of knowledge" (Shulman, 1986, p. 10). Forms of knowledge can expand content knowledge, pedagogical knowledge, and PCK through different methods of inquiry and presentation of information. Propositional knowledge originated in research, experience, and morals and ethics of individuals, communities, or institutions (Shulman, 1987). Research supported both content selection and pedagogical choice and implementation, thus forming principles that guided the formation of PCK (Shulman, 1987). Experience from the practice of educators forms another component of propositional knowledge. Experiential knowledge can be transferred through sharing pedagogy between colleagues and through research (Shulman, 1986, 1987). Moral and ethical norms constitute the final component of propositional knowledge and may vary depending on individuals, communities, and contexts. Norms can impact the prioritizing of content and the valuing of differing pedagogies (Shulman, 1986).
Case knowledge provides a means for both studying and sharing content, pedagogical, and PCK (Shulman, 1970, 1986). Case knowledge can be inclusive of practical and theoretical observations and reasoning. Prototypical case knowledge can represent propositional research-based principles that inform content and pedagogical decisions (Shulman, 1970, 1986). Experiences of PCK illustrated in case knowledge can serve as precedents or as allegories that present moral and ethical decisions impacting PCK (Shulman, 1986). Case knowledge supported through research can be a source of learning as well as a method for sharing information related to education (Shulman, 1970, 1986).

Skills and principles of research-based propositional knowledge can combine with practical approaches and the applications of case knowledge to form a more complete view of pedagogical, content, and PCK (Shulman, 1986). Shulman (1986) termed this knowledge as "strategic" (p. 10) and a means for avoiding a singular point of view driven by either content or pedagogy. Strategic knowledge supports PCK as both incorporate varied perspectives of teaching and learning to enhance educator practice. The importance of knowing both what to teach and how to teach through the combining of propositional and case knowledge supports the merger of content knowledge and the pedagogical knowledge in the reasoning and implementation of PCK (Shulman, 1986).

Due to PCK incorporating varied perspectives inclusive of and reliant on both content knowledge and pedagogical knowledge, propositional, case, and strategic knowledge all contribute to the overall process of planning, implementing, assessing, reflecting on, and improving teacher practice (Shulman, 1986). Magnusson et al. (1999) incorporated general strategies and learning with strategies specific to content areas such as science. The bringing together of different knowledge forms and categories aid in broadening beyond unilateral
approaches through interdisciplinary perspectives of the cycle of PCK development and practice (Magnusson et al., 1999; Shulman, 1970, 1983, 1986, 1987). This integration of knowledge forms can broaden sources of PCK beyond the experiences of a single individual and therefore provide a wider base of support in developing PCK (Magnusson et al., 1999; Shulman, 1986, 1987).

**Critique of PCK.** Shulman’s (1986, 1987) theory of PCK provides a framework for explaining the interaction between content knowledge and pedagogical knowledge, but four primary critiques of PCK have been presented in the literature (Ball, Thames, & Phelps, 2008; Bednarz & Proulx, 2009; Blomeke, Felbrich, Muller, Kaiser, & Lehman, 2008; Friedrichsen et al., 2010; Huillet, 2009; Salderholm, Ronau, Brown, & Collins, 2010). The first critique is founded in the lack of empirical evidence to support PCK as a component of teacher practice (Ball et al., 2008). Shulman’s (1986, 1987) construct of PCK is primarily theoretical based on observations. This lack of supporting empirical research resulted in difficulty separating the content knowledge and pedagogical knowledge constructs from PCK (Ball et al., 2008; Baumert et al., 2010; Bednarz & Proulx, 2009; Blomeke et al., 2008; Huillet, 2009; Salderholm et al., 2010). Shulman’s (1986, 1987) presentation of PCK as transformative to teacher practice is contrasted by the integrative model presented by Gess-Newsome (1999). The lack of empirical evidence weakens the presentation of PCK as a means of transforming instruction (Ball et al., 2008; Baumert et al., 2010; Gess-Newsome, 1999).

The research of Bednarz and Proulx (2009) identified Shulman’s (1986, 1987) presentation of PCK as a fixed quantity. PCK that is acquired in one setting and then applied in another situation limits the ability of PCK to change without learning and conscious reflection. In contrast, PCK as a dynamic component of instruction can evolve within a current
implementation, such as a teacher developing and implementing PCK within a classroom lesson to address content, pedagogy, and interactions in the moment (Bednarz & Proulx, 2009).

Shulman’s (1986, 1987) proposed PCK as a fixed construct may be expanded to include a dynamic quality (Bednarz & Proulx, 2009). The presentation of PCK as evolving throughout all experiences would move beyond the need for separate learning to be internalized in one setting prior to application in a different situation (Bednarz & Proulx, 2009).

Early conceptions of PCK presented by Shulman (1986, 1987) have been critiqued as being too narrow and lacking acknowledgement of the importance of strategies, presentations, and student characteristics (Depaepe et al., 2013). Grossman (1990) identified a need to broaden PCK to include knowledge of curriculum. Non-cognitive domains have also been identified as lacking in the conceptualization of PCK (Friedrichsen et al., 2010; Shulman, 2015; Zembylas, 2007). The inclusion of non-cognitive factors, such as beliefs and emotions, can support the explanation of interactions between content and pedagogy as well as between students and teachers (Friedrichsen et al., 2010; Zembylas, 2007). Broadening the focus of PCK can include additional knowledge that impacts instruction.

Finally, the development of PCK has been identified as a normative process that draws from existing, accepted culture and standards (Ball et al., 2008; Tirosh, Tsamir, Levenson, & Tabach, 2011). Pedagogical content knowledge built on existing frameworks did not allow teachers to develop beyond what has been deemed culturally acceptable or standardized (Ball et al., 2008; Tirosh et al., 2011). While Shulman (1986, 1987) advocated a balance of content and pedagogy that could expand visions of evaluation, the restrictions of a normative environment described by Ball et al. (2008) and Tirosh et al. (2011) limit true development of individual PCK.
Moving beyond the normative constraints of culture and standards could improve the development of PCK (Ball et al., 2008; Tirosh et al., 2011).

**Revision of PCK.** Applications of PCK in varied contexts and subsequent critiques have resulted in revisions to Shulman’s (1986, 1987) theory of PCK. General revisions applied to PCK addressed the narrow scope and static nature of Shulman’s (1986, 1987) PCK. Kind (2015) proposed revisions to the application of PCK specific to science instruction and described PCK in science as a continuum of instruction. Shulman’s (1986, 1987) theory of PCK was expanded by general and science-specific revisions and explained teacher approaches to instruction.

**General revisions of PCK.** In response to critiques of the narrow focus and application of PCK, models of PCK were developed to include non-cognitive domains (Depaepe et al., 2013; Friedrichsen et al., 2010; Shulman, 2015; Zembylas, 2007). The theory of PCK was broadened by Friedrichsen et al. (2010) to include teacher beliefs in the construction of PCK. Zembylas (2007) included emotion as another non-cognitive domain of PCK. The inclusion of teacher beliefs and emotions provided a broader understanding of the context and interactions with students (Depaepe et al., 2013; Friedrichsen et al., 2010; Shulman, 2015; Zembylas, 2007).

Cochran, DeRuiter, and King (1993) proposed a shift from PCK to “pedagogical content knowing” (p. 266) to communicate a framework that is more dynamic than Shulman’s (1986, 1987) definitions of PCK. Pedagogical content knowing includes the constructs of pedagogical knowledge and subject matter knowledge along with knowledge of student characteristics and the contexts in which the learning takes place (Cochran et al., 1993). The addition of information in the model of pedagogical content knowing proposed by Cochran et al. (1993) parallels suggestions by Grossman (1990) and Marks (1990) that include knowledge of curriculum, knowledge of instructional materials, student understanding, and purposes of instruction. The
inclusion of additional components both improve the responsiveness and broaden the scope of PCK (Cochran et al., 1993; Grossman, 1990; Marks, 1990).

**Revisions of PCK in science.** Kind (2015) presented PCK in science as a continuum that ranges between integrative and transformative. Educators can integrate subject matter, pedagogical knowledge, and educational contexts. Moving along the continuum, transformative approaches move beyond integration to transforming the three domains into new learning and new opportunities for students (Kind, 2015). As science educators consider the different demands of science curricula, including content matter, practices, and literacy, they must integrate and transform the pieces of science curricula into cohesive learning experiences and opportunities. This process relies on each educator’s PCK (Kind, 2015; Schneider, 2015; Tobin & McRobbie, 1999).

As discussed previously, current reiterations of PCK included student outcomes and non-cognitive domains (Shulman, 2015). When applied to science, PCK can include components of teacher orientations and assessments of outcomes evidenced by Grossman (1990), Magnusson et al. (1999), and Park and Oliver (2008). This shift in the application of PCK is important when considering the use of practices to construct and communicate science knowledge (Magnusson et al., 1999; NRC, 2012; Park & Oliver, 2008). The inclusion of assessment by Magnusson et al. (1999) and Park and Oliver (2008) was illustrated as a component in Park and Oliver’s (2008) pentagon model that also includes curricula and programs, purposes of education, student conceptions and misconceptions, and instructional strategies. When viewing PCK in science education, attention needs to be given to expected outcomes, including assessment of student learning due to presented opportunities and practices (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008).
Emphasis on the development and application of PCK in relation to student learning progressions responds to the importance of overall educational goals or outcomes (Grossman, 1990; Shulman, 1986, 1987). To meet established educational expectations in science, educators must understand the content and pedagogy of science, including the practices that students must master in order to engage with science content and in science communities (Spiegel et al., 2010). Shulman’s (1986, 1987) highlighting of content knowledge as essential for teaching can be coupled with current research of PCK to include content knowledge of how scientists engage in practices to understand and produce knowledge. Engagement in practices and content relies on pedagogy for the creation of opportunities and learning experiences (Shulman, 1986, 1987). The theory of PCK is supported by the individual constructs of content knowledge and pedagogical knowledge merging or influencing beliefs and practices of the educator that impact the understanding of students and development of learning environments specific to the educator, student, and content of instruction (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1986, 1987).

Science educators must possess content and pedagogical knowledge in the science domain being taught (Shulman, 1987). Magnusson et al. (1999) demonstrated processes for developing the PCK of science educators. As discipline-specific educators are called on to implement and support literacy instruction, instructional shifts must be cautious to avoid overshadowing the importance of content within disciplines. Educators must develop both disciplinary PCK and disciplinary literacy PCK to provide instruction that effectively creates balanced learning opportunities for students (Faggella-Luby et al., 2012; Shanahan & Shanahan, 2008; Shulman, 1986, 1987).
Pedagogical Content Knowledge of disciplinary literacy in science. In science education, understanding of science content has been identified as insufficient for teaching without supporting literacy pedagogy (Norris & Phillips, 2003; Spiegel et al., 2010; Yore, 2004). Pedagogical knowledge may be generalized, as evident in content area literacy approaches. However, pedagogical knowledge contains specificity to disciplinary content due to variations in the representations and uses of information (Houseal et al., 2016; Park & Oliver, 2008; Shulman, 1986, 1987). The inclusion of literacy in disciplinary instruction requires pedagogical knowledge relative to the use of literacy within the discipline (Fang & Coatoam, 2013; Moje, 2007, 2015; Spiegel et al., 2010; Yore, 2004). Educators need to have pedagogy for science content and literacy instruction (Fang & Coatoam, 2013; Moje, 2015). Without understanding both science and literacy pedagogy, educators will be less prepared to integrate literacy in disciplinary contexts (Fang & Coatoam, 2013; Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015).

Research supports a shift in literacy instruction that moves from the idea that every teacher is a reading teacher to a discipline-based approach to literacy instruction that is more authentic to the discipline in which literacy is being taught (Shanahan & Shanahan, 2008). Such a shift is proposed as an emphasis on the use of practices that are authentic, relevant applications of literacy to real-world uses of literacy in various disciplinary contexts (Moje, 2015; Shanahan & Shanahan, 2008). The movement to utilize a disciplinary approach to literacy instruction assumes a level of content or disciplinary literacy knowledge possessed by teachers of the disciplines, especially at the middle and secondary levels where courses become more content based. Considering Shulman's (1986, 1987) theory of PCK, disciplinary literacy instruction can be defined as a balance of both the content of discipline concepts and literacy uses and the
pedagogy for doing or using literacy in the discipline. Shulman (1986) proposed that teaching must consist of an overlap of content knowledge and pedagogical knowledge, which could be applied to the integration of disciplinary literacy within disciplinary content-focused coursework as evidenced in recommendations for teachers to use pedagogy that models disciplinary literacy practices and scaffolds student use of disciplinary literacy practices (Goldman et al., 2016; Moje, 2015; Shanahan & Shanahan, 2008).

Pedagogical content knowledge is necessary for effective and meaningful instruction. Rather than applying the general pedagogical methods described in earlier research, approaches should recognize the balance of pedagogy and content knowledge in disciplinary literacy instruction (Faggella-Luby et al., 2012; Fisher et al., 2009; Shanahan & Shanahan, 2008). Interactions between content and pedagogy best suited for instruction of disciplinary conceptual and literacy content may result when considering shifts from content literacy to disciplinary literacy suggested by Shanahan and Shanahan (2008). Shifts in instruction can result in authentic application of literacy based on interactions of content knowledge, literacy knowledge for the discipline, and relevant pedagogy specific to the discipline (Shanahan & Shanahan, 2008; Shulman, 1986, 1987).

Disciplinary literacy instruction is a topic of the discipline or content area, occurs within disciplinary classrooms, and is guided by the content teacher. Therefore, disciplinary literacy fits within Shulman’s (1986) theory of PCK. The PCK of disciplinary literacy combines content and skills to improve student literacy in the discipline and transfer of literacy skills outside of the classroom setting to authentic disciplinary practice (Moje, 2015; Shanahan & Shanahan, 2008). Shulman’s (1986, 1987) theory of PCK can be applied to and guide development of disciplinary literacy instruction. This development of instruction depends on pedagogy for both science

The fusion of content and pedagogy in PCK allows for the transformation of learning that allows the educator to connect with diverse learners and diverse approaches to instruction and learning. Varied approaches that link content with appropriate pedagogy can make learning meaningful and memorable for learners and relevant to the context (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1987). Development of PCK can focus on student characteristics and needs, such as those identified through research on writing deficits for students across the United States (Gillespie et al., 2014; Graham et al., 2014; Kiuhara et al., 2009; Shulman, 1987). Successful implementation of disciplinary literacy in content areas relies on PCK to provide authentic discipline-based opportunities and experiences for practicing literacy (Fang & Coatoam, 2013; Moje, 2015).

Science and literacy PCK. In the science discipline, instruction, including literacy practices, often focuses on answering questions or solving problems and involve various texts that may include models, diagrams, and data sets (Goldman et al., 2016; Houseal et al., 2016; NGSS Lead States, 2013; Wilson et al., 2014). Following Shulman’s (1987) theory of PCK as applied to science by Magnusson et al. (1999) and Park and Oliver (2008), effective disciplinary literacy instruction in science should be designed to meet the purposes of science as related to authentic texts and desired outcomes of science instruction. Teacher knowledge of the content purposes of disciplinary literacy and pedagogy is required for planning and implementing disciplinary literacy instruction in science. The combination of knowledge and pedagogy can
transform literacy in ways that are valuable for students in learning and application of
disciplinary literacy in science (Goldman et al., 2016; Shulman, 1987; Wilson et al., 2014).

Disciplinary literacy instruction represents a shift that focuses on authentic integration of
literacy skills and requires an understanding of the context and purpose that supports the use of
literacy skills and strategies specific for a discipline or topic within the discipline (Moje, 2015;
Shanahan & Shanahan, 2008). Developing PCK can guide the process of transforming literacy
skills and strategies into instruction that is understandable and meaningful to students.
Instruction in disciplinary literacy requires the understanding of content structures in disciplinary
literacy (Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1987). The characteristics of
learners in the disciplines contributes to the use of disciplinary literacy instruction to achieve
understanding and application of learning (Goldman et al., 2016; Houseal et al., 2016; NGSS
addressed the combination of educator knowledge and practices, specifically including
characteristics of learners, context, and purpose as components of knowledge, which can be
related to the needs of disciplinary literacy instruction (Goldman et al., 2016; Shanahan &
Shanahan, 2008). The application of PCK provided a framework that can be used to examine
teacher knowledge of disciplinary literacy skills and the pedagogy applied when delivering
disciplinary literacy instruction (Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1986,
1987).

**Summary of theoretical framework.** Shulman’s (1986, 1987) initial theory of PCK has
been further developed to meet the needs of science education through transformative application
of content knowledge, pedagogical knowledge, and the interaction of these constructs to form
PCK (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008). The shift in literacy
instruction proposed by Moje (2008) and Shanahan and Shanahan (2008) required teacher knowledge of disciplinary content, literacy content, disciplinary literacy, and literacy pedagogy. The interactions of content and pedagogical knowledge of disciplinary literacy form the impetus that can drive the desired shifts in literacy instruction. Additional study of educator PCK of disciplinary literacy can improve the understanding of interactions that lead to successful implementation of disciplinary literacy in the science classroom (Moje, 2015; Shanahan & Shanahan, 2008; Shulman, 1987).

**Chapter Summary**

The re-emphasis or shift in literacy instruction in the disciplines is evident in the development of standards for teaching science (Faulkner, 2012; Hannant & Jetnikoff, 2015; MacMahon, 2014; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Tang, 2016). Changes in literacy instruction have centered on transitions from content area literacy approaches prescribed by Herber (1970) to approaches aligned with authentic uses of literacy by disciplinary experts suggested by Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015). Educator understanding of disciplinary content and pedagogy and literacy content and pedagogy are requirements of teaching literacy skills relevant to the disciplines and uses by experts (Moje, 2008; Shanahan & Shanahan, 2008, 2015). The educator must be able to make both literacy and content accessible to students, which includes pedagogy and content for both literacy and the use of literacy in developing content knowledge (Norris & Phillips, 2003; Shulman, 1987). The application of skills, such as science and engineering practices, can be used to incorporate reading, writing, and speaking and listening in ways consistent with disciplinary uses (NGACBP & CCSSO, 2010; NGSS Lead States, 2013).
Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015) presented disciplinary literacy instruction as a method for reforming literacy instruction within content-specific courses but disciplinary literacy is not without critique. Brozo et al. (2013) and Faggella-Luby et al. (2012) presented views that advocated for a balanced approach to literacy instruction within the disciplines. Critiques included the suggestion by Brozo et al. (2013) that instruction at either the content area literacy or disciplinary literacy extreme would compromise holistic literacy instruction. Faggella-Luby et al. (2012) included the need for content area literacy instruction to aid development of either specific skills for all students or a range of skills within specific subgroups of students. Critiques reported by Brozo et al. (2013) and Faggella-Luby et al. (2012) called for balance in literacy instruction.

Shulman (1986, 1987) developed the theory of PCK to address the interaction of the constructs of content knowledge and pedagogical knowledge in the creation of PCK. The construct of PCK drives teacher planning and instructional decisions and can be developed through development opportunities and teaching experience (Shulman, 1986, 1987). The theory of PCK was critiqued as lacking empirical evidence, being a fixed construct, too narrow, and normative to a dominant culture (Bednarz & Proulx, 2009; Depaepe et al., 2013; Ball et al., 2008; Tirosh et al., 2011). Revisions to PCK in response to these critiques include broadening the theory to include non-cognitive domains and representing PCK as a continuum rather than discrete constructs (Friedrichsen et al., 2010; Kind, 2015). The theory of PCK and revisions can be applied to content and pedagogical knowledge for both science and literacy teaching.

Chapter 2 presented the progression of literacy understanding in discipline-specific courses from content area literacy approaches to the concept of disciplinary literacy instruction (Fisher & Ivey, 2005; Herber, 1970; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). The
theoretical construct of Shulman’s (1986, 1987) theory of PCK, critiques, and revisions were overviewed. Chapter 3 will elaborate on procedures and methods for researching disciplinary literacy.
Chapter 3: Procedures and Methods

Literacy instruction has been an area of focus in research and instruction for over four decades (Fisher & Ivey, 2005; Herber, 1970; Moje, 2008; Shanahan & Shanahan, 2008). Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015) presented a reconceptualization of literacy instruction in which they advocated moving away from broad, general strategies and toward the use of literacy practices that are specific to each discipline. While some research has found promise in developing preservice educators and their efficacy to embed disciplinary literacy into content instruction, limited exploration of the practices of in-service educators has been completed (Colwell & Enderson, 2016; Goldman et al., 2016; Hart & Bennett, 2013; Ingram et al., 2016; Tang, 2016). Qualitative studies focused on preservice science educators have revealed the need for establishing the importance of literacy, connecting literacy with content, and providing collaborative opportunities for developing disciplinary literacy skills (Colwell & Enderson, 2016; Hannant & Jetnikoff, 2015; Hart & Bennett, 2013; Ingram et al., 2016). Mixed methods studies focused on both preservice and in-service educators have been used to gauge educator perceptions of literacy instruction in the content area through self-report surveys, proportion of instructional time inclusive of literacy, and the efficacy of interventions taught through development sessions or coursework (Goldman et al., 2016; Hannant & Jetnikoff, 2015; Tang, 2016).

Some research has focused on the learning and implementation of guided literacy instructional programs by both preservice and in-service educators (Goldman et al., 2016; Hannant & Jetnikoff, 2015). However, current research lacked investigation of practices that move disciplinary literacy from a conceptualization of literacy instruction to actual practice separate from these prescribed programs (Faggella-Luby et al., 2012; Fang & Coatoam, 2013;
Tang, 2016). These gaps in current literature reveal that more research is needed on educator PCK and behaviors that encourage disciplinary literacy instruction consistent with contemporary standards and expected outcomes. To address these gaps, research needs to be centered on how and why educators plan and implement chosen learning opportunities, which can be accomplished through the use of qualitative research procedures and methods. Research on how in-service educators adapt instruction to meet expectations for disciplinary literacy and content instruction is the focus of the study as guided by the following overarching research question: What do science educators in an urban middle school know about and do to implement disciplinary literacy instruction in the science classroom? Following from this overall question, the research may include the following sub-questions:

**RQ1:** What are the prior disciplinary literacy knowledge, training, and development experiences of science educators?

**RQ2:** What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of reading skills?

**RQ3:** What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of writing skills?

**RQ4:** What do participating science educators at the urban middle school do in the implementation of science instruction to support speaking and listening skills?

**RQ5:** What do participating science educators at the urban middle school do in the implementation of science instruction to integrate literacy skills and science and engineering practices?
Based on the need to understand how educators implement disciplinary literacy in content classrooms, a qualitative study can be implemented to gather information about educator actions related to disciplinary literacy instruction (Stake, 1995; Yin, 2014).

The methodology and methods of the study will be presented in this chapter beginning with a discussion of the qualitative paradigm and the qualitative case study research design. The selection of the site will be presented followed by a description of the population and selection of participants. Ethical issues and permissions will be discussed. Description of the research will include data sources, protocols used, and data collection procedures. Researcher positionality will be presented along with methods for ensuring trustworthiness and rigor. Techniques for analyzing data will be discussed prior to a summary of methodology and methods at the conclusion of the chapter.

**The Qualitative Paradigm**

Quantitative research applied through experimental or quasi-experimental methods has been identified as being generalizable beyond the participants of the study (Campbell & Stanley, 1963; Yin, 2014). However, the use of such methods can be limited in exploring and explaining questions related to the how and why of an applied concept, practice, or behavior (Stake, 1995; Yin, 2014). As some researchers have identified the need for changes in literacy instruction practices and proposed solutions through disciplinary literacy approaches, more information about the implementation of disciplinary literacy approaches is necessary to understand how educators apply disciplinary literacy instruction to further classroom practice and impact student skills and achievement (Fisher & Ivey, 2005; Moje, 2008; Shanahan & Shanahan, 2008). The limitations of quantitative research in describing how practices are applied and the need for a better understanding of disciplinary literacy instruction inform the use of qualitative methods for
researching the how and why of teacher practice, including the use of PCK related to disciplinary literacy instruction in science classrooms.

The qualitative paradigm consists of research that explores a problem or phenomenon. Qualitative research focuses on exploration and description that is not focused on testing variables and presentation of numerical quantifications of interventions (Bogdan & Biklen, 2007). Qualitative procedures and methods can be used in research to develop an understanding of questions based on identified needs. In contrast to experimental and quasi-experimental quantitative designs inclusive of variable manipulation, qualitative methods describe and analyze programs or practices as they occur or are implemented (Bogdan & Biklen, 2007; Campbell & Stanley, 1963).

**Strengths of the qualitative paradigm.** The qualitative paradigm is not limited in focus by the evaluation of specified variables but examines the holistic nature of a problem or phenomenon in authentic contexts (Bogdan & Biklen, 2007; Yin, 2014). Strengths of the qualitative paradigm include the focus on understanding programs as they are implemented, the use of multiple sources of information, and the synthesis of a variety of information (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). The focus on understanding programs or practices as they are implemented represents one strength of qualitative methods in gathering information to understand and address relevant issues in a manner that captures the participants’ intent in context. Qualitative approaches used within settings not manipulated by the researcher provide opportunities for more complete, deeper understanding of how and why outcomes result from behaviors or practices (Creswell, 2014; Stake, 1995; Yin, 2014).

Another strength of qualitative procedures and methods is the use of multiple sources of data to inform conclusions. Both inductive and deductive reasoning may be utilized in the
analysis of data. Actions of science educators, from planning through implementation, assessment, and reflection, will be studied. Each of these components can inform the process of developing or using PCK that impacts literacy instruction as educators transition from content area literacy strategies to real-world applications of disciplinary literacy in science. Through analyses of these components, the researcher can play a key role in bringing together data points and perspectives that reform a holistic representation of information and interpretations of collected data (Creswell, 2014; Stake, 1995; Yin, 2014).

Qualitative case study methods allow the researcher to synthesize information from various sources to assist in better understanding a topic. The data points and perspectives of qualitative research are expanded through the use of multiple case studies and can answer how or why research questions (Stake, 1995; Yin, 2014). Through addressing questions that represent how and why actions or events occur, qualitative research can deepen understanding through descriptions of selected cases. Multiple case studies allow for comparison of themes generated from different cases and can bring together these themes and perspectives to aid in understanding the richness of the experiences of participants (Yin, 2014). Qualitative methods are not intended to produce results that are broadly generalizable, but descriptions and themes developed may be transferred or related to other cases. Through the comparison of cases, data related to how and why, and the themes developed, qualitative case study research can address research needs that cannot be determined through traditional qualitative methods. The use of multiple case study qualitative methods provides the opportunity to compare different cases and inform current understanding and future research (Stake, 1995; Yin, 2014).

**Weaknesses of the qualitative paradigm.** While the role of the researcher allows for strengthening interpretations based on direct observation, the involvement of the researcher can
also present a weakness in qualitative procedures and methods. Researcher positionality and bias can influence interpretations if precautions are not taken to minimize these impacts. Acknowledging researcher positionality and bias can be viewed as the first steps in accounting for and addressing this weakness (Bogdan & Biklen, 2007; Creswell, 2014; Stake, 1995; Yin, 2014).

Qualitative methodologies often involve data collection and analyses that require researcher presence and are time consuming, therefore limiting the sample size that is practical in an investigation. Due to small sample sizes associated with some qualitative approaches, qualitative studies are not meant to be generalizable. Qualitative procedures and methods are often identified as having limited generalizability when compared to quantitative methods and analyses. This limitation may be viewed as a weakness of the qualitative paradigm but does not preclude value and transferability of data and conclusions derived from qualitative procedures and methods (Creswell, 2014; Stake, 1995; Yin, 2014).

The qualitative paradigm in relation to research questions. The study of shifts in literacy instruction in the science discipline can focus on educator PCK necessary for transforming knowledge into practice. The changes in literacy instruction require teachers to use different science and literacy knowledge to teach students (Moje, 2007; Shulman, 1987). Shulman (1986, 1987) described the importance of context as a consideration of PCK when reasoning, planning, and implementing instruction. Qualitative research methods suit the need for understanding the cognitive, hidden mental processes of using PCK that cannot be adequately probed using quantitative methods (Shulman, 1974, 1987). Qualitative methodologies can aid in
probing and reporting characteristics of educator PCK and shifts to disciplinary literacy instruction (Shanahan & Shanahan, 2008; Shulman, 1987; Stake, 1995).

To understand teacher knowledge and practices, the theory of PCK first introduced by Shulman (1986) and later refined for science instruction by Grossman (1990), Magnusson et al. (1999), and Park and Oliver (2008) will be applied to the study. The focus of the study will review the shift from content area literacy to disciplinary literacy centered on reading, writing, speaking and listening, and science skills and practices (NGACBP & CCSSO, 2010; NGSS Lead States, 2013). Teacher knowledge and practices related to these components and the development of this knowledge encompass the how and why of teacher implementation of disciplinary literacy instruction, thus supporting the use of qualitative procedures and methods (Stake, 1995; Yin, 2014).

Qualitative research questions often focus on fostering discussion of what and how (Stake, 1995; Yin, 2014). Consistent with these recommendations, the proposed research study will investigate the strategies or methods that teachers use to implement disciplinary literacy in science instruction as guided by the following overarching research question: What do science educators in an urban middle school know about and do to implement disciplinary literacy instruction in the science classroom? Data on teacher knowledge and practices related to science content and literacy collected through case study methods will inform interpretations of disciplinary literacy instruction to allow for better understanding and implementation of disciplinary literacy instruction.

**Qualitative Method**

The exploration of disciplinary literacy instruction in science classrooms represents a problem or phenomenon that can be studied using the qualitative paradigm. The qualitative
paradigm includes a variety of methods for data collection (Bogdan & Biklen, 2007). Teacher instruction in science classrooms represented cases to be explored, therefore supporting qualitative case study methods. Stake (1995) and Yin (2014) supported the use of qualitative case study methods for exploring the actions of individuals to gain perspective and understanding of these actions. The planning, implementation, and reflection of instruction by each teacher therefore fit within the qualitative case study methods and procedures (Stake, 1995; Yin, 2014).

Shulman (1987, 1998) promoted the use of case knowledge for reflecting on, teaching, and learning about experiences that support the development of PCK. Building case knowledge requires the collection and analyses of case study data (Shulman, 1998; Stake, 1995; Yin, 2014). Qualitative methods, including case study methods, can reflect experiences and understanding of educator actions that can inform considerations of PCK for disciplinary literacy in the researched context and possibly inform future research (Shulman, 1987; Stake, 1995). Additionally, Shulman (1998) presented the value of case studies in illustrating the complexity of pedagogy through documentation and analyses of a series of experiences to be used in reflective practices that improve PCK. The implementation of disciplinary literacy instruction and the necessary PCK that drives these instructional decisions are not fully explicated in literature, thus indicating the need for additional study of disciplinary literacy and educator PCK that influence the implementation of disciplinary literacy (Buczynski & Hansen, 2010; Chapoo et al., 2014; Chowdhary et al., 2014; Moje, 2015; Rozenszajn & Yarden, 2014; Shanahan & Shanahan, 2008; Stasinakis & Athanasiou, 2016). A descriptive, multiple case study design was used to gather data on teacher practices of planning for, implementing, assessing, and reflecting on disciplinary
literacy instruction as a means for describing teacher actions related to such instruction in the science classroom (Yin, 2014).

To understand the processes of pedagogical reasoning and action described by Shulman (1987) in the development of PCK, case study methods included analyses of observable actions and interviews to explore mental processes during planning and implementation of instruction resulting from PCK (Stake, 1995; Yin, 2014). Yin (2014) described six types of case studies used to explore, describe, or explain the question of study. Determining the relationship of PCK and disciplinary literacy instruction in the science discipline requires insight into educator knowledge and practice on disciplinary concepts and literacy. Learning and communicating the structures of PCK for disciplinary literacy was completed through descriptive case study (Shulman, 1987; Yin, 2014). The study used the selected cases to understand disciplinary literacy instruction and PCK fits Stake's (1995) instrumental case study.

Methods for case study research as described by Stake (1995) and Yin (2014) recommend gathering data from multiple sources and varied perspectives to improve interpretations and credibility of the case study. Multiple case study methods allowed for cross-case analysis and synthesis of data composed of different perspectives and actions (Yin, 2014). Each participant represented a case within the study and the use of observations, interviews, and document reviews represented varied sources of data from each case. Different data sources can be used to clarify interpretations of information and determination of meaning from participants within each case (Stake, 1995; Yin, 2014).

Descriptive case study was used in researching multiple cases. When used with multiple cases, the different cases were contrasted as a means for gaining understanding (Yin, 2014). A multiple case study including cases for each of three participants allowed for contrasting the
content and pedagogical knowledge used by educators with different training, experiences, and roles. A descriptive, multiple case study with participants of science backgrounds detailed varied methods of implementing literacy instruction and illustrated how and why educators implement disciplinary literacy instruction in science classrooms.

Site Selection

Qualitative methods require researcher presence for data collection. Due to this necessity, the researcher selected a site that was accessible (Stake, 1995). Accessibility of the site included permissions to engage in research, but the site was also near the researcher so as not to require extended periods of travel. The locale of the site near the researcher facilitated visits to the school for observations and interviews. Following the guidelines of Stake (1995), the site selected was in close geographic proximity to the researcher and was therefore convenient and accessible.

Bram Middle School (a pseudonym) is an urban, Grades 6-8 middle school located in the northeastern United States. The school is located on the edge of the city limits and is surrounded by fields and residential areas. The school setting does not invoke an urban feel due to its location in a more affluent section of the city that is removed from the urban center and surrounded by open areas. However, the student population at Bram Middle School (BMS) reflects the racial and ethnic diversity of the city as a whole.

Typicality of the site. Disciplinary literacy is identified as relevant to education as courses become departmentalized (Shanahan & Shanahan, 2008). The division of subjects commonly occurs during the middle and secondary levels of schooling in the United States. To aid the investigation of disciplinary literacy instruction, the BMS employed a structure in which courses are departmentalized and are taught by discipline. The school was made up of eight
academic teams that each contained the four core content areas of English language arts, mathematics, science, and social studies. All students housed on a team received instruction from the same four content teachers, which included science courses taught by educators with appropriate state teaching certifications for grade level and subject matter.

Stake (1995) recommended cases that could be described as typical. The site is considered an urban district, and educators are certified to teach the grade level and content matter. The nature of the site as a middle level school with science courses taught separately from other disciplines represented a typical school structure in the United States. Demographics within the site were reflective of the make-up of the surrounding community and region. Based on public information provided by the district in 2016-2017, BMS serves approximately 760 students in Grades 6-8. Demographics are reflective of the city in which the school is located. Gender distribution is identified by the district as 54% male and 46% female. The largest district identified subgroup of students is Caucasians (65%), followed by Hispanic (22%) and African-American (8%). The lowest percentages of students were identified as Asian and multiple race, each at 2.5%. Over 47% of students participate in the National School Lunch Program by receiving free and reduced-price breakfast and lunch. The percentage of participation in the lunch program is higher than the overall percentage of participation for both the district and state averages and qualifies the school to receive Title I funding, federal monies awarded to schools based on percentages of students in need served by the school. Nearly 20% of students at BMS receive special education support services. Student achievement in literacy at the school, as measured by state mandated standardized testing, is slightly below the district and state achievement on the state reading and writing assessment. The BMS has a proficiency rate on
state literacy assessments of 51%, which is lower than the district and state rate of 55% of students scoring proficient or better in 2017.

**Description of physical characteristics.** The physical plant of BMS is a rectangular brick structure containing team pods for eight academic teams consisting of four content teachers and a special education teacher. At the time of the study, the eight academic team pods consisted of three Grade 6 teams, two Grade 7 teams, two Grade 8 teams, and one split team that is half Grade 7 and half Grade 8. The academic teams are housed in a three-story portion of the building set behind a front, two-story section of the building dedicated to administrative offices and non-core content area classrooms.

Each of the three science classrooms has the same permanent fixtures. One wall of the classroom includes three large windows overlooking a grassy area bordered by a wooded lot. Counter tops are along three walls, including under the windows. Five sinks, an eyewash station, and a hand-held shower station are spaced on the counter. On two walls above the counter are cabinets. In the space between the counter top and the cabinets is bulletin board material. In the center of the front wall there is an analog clock synchronized with the clocks in other classrooms. Each classroom has either a whiteboard or chalkboard at the front of the room flanking an interactive (SMART) whiteboard. The science classrooms have tile floors and lab tables that seat two students, which differs from other classrooms that have carpeted floors and individual student desks.

**Relationship of the phenomenon to the site.** The selected site is a public middle school that is impacted by curricular standards adopted at the state and district levels. The site housed eight science educators engaged in teaching science and therefore contains individuals who are engaged in teaching science. Furthermore, the site emphasized literacy instruction across subject
areas, which also aligns with the problem of using disciplinary literacy to foster literacy learning in the science content area. The selected site demonstrated the phenomenon due to the structure of the site as a Grades 6-8 middle school with disciplinary courses taught as separate subjects by certified educators.

Literacy has become a focus as components of academic standards and is consequently a focus of public school districts that are required to follow state adopted standards and mandates. As previously stated, the selected site was a public school and therefore influenced by state adopted standards. The school was located in a state that had adopted the CCSS and the NGSS, both of which guide literacy instruction in the science discipline (NGACBP & CCSSO, 2010; NGSS Lead States, 2013). The district in which the site was located had identified literacy instructional goals of expanding current implementation of reading and writing instruction from the K-5 level to the middle level, including interventions for students struggling with reading and writing components of literacy. The literacy goals established by the district acknowledged the need for varied practices and interventions that would not simply maintain literacy skills and achievement but would result in improved literacy as measured on classroom and state mandated standardized assessments. Vertical alignment, the progression of instruction between grade levels, of literacy instruction coupled with modeling and coaching for middle level content teachers represented action steps that will positively influence the integration of literacy instruction in content classrooms. The emphasis on literacy in each of the district's schools supported the relevancy of disciplinary literacy research.

Accessing the site. The selected site represented a typical site that contained the problem that represented the focus of this study. As discussed previously, the site was geographically accessible by the researcher (Stake, 1995). To gain access to the site, the researcher initiated e-
mail contact with the principal at the site. A meeting was scheduled with the principal at the site. During the meeting at the site, the researcher presented the research proposal to the principal. The principal agreed to allow the research access to the site contingent on district approval for access.

District approvals for access were controlled by the school district superintendent. A request for permission to access the school site was presented to the superintendent through e-mail communication. The superintendent approved the request for access to the site (Appendix A). This district permission was then included in an application for university Institutional Review Board (IRB) approval. University IRB approval (Appendix B) was granted prior to the recruitment and selection of participants for the study.

Participants

The purpose of the study was to explore disciplinary literacy instruction in middle level science classrooms. Consistent with this purpose, the study participants needed to be middle school science educators. A requirement of participants included being certified or designated as highly qualified by state department of education standards in the area of Grades 6-8 science. Participants also needed to be currently teaching science at the selected site. Therefore, current middle level science teachers who were state certified in grade level and content presented a typical population intended for study.

The problem being studied focused on the implementation of literacy instruction by science educators in science classrooms, specifically with a focus on the integration of disciplinary literacy and science practice instruction. Therefore, participants who are certified science educators currently engaged in teaching science at the middle school level represents the phenomenon being studied. The work of participants in addressing literacy and science
instruction is illustrative of the problem of disciplinary literacy instruction being studied. In addition to participants who are certified in and currently teaching science, the eight potential participants within the site included educators with varied levels of experience, which may impact PCK focused on literacy instruction in the science discipline (Shulman, 1986, 1987). Educators with different levels of experience and training included varied perspectives related to disciplinary literacy instruction in the science classroom.

**Participant Selection**

Case study methodologies are not intended to be generalizable, but such studies can be credible with a small sample size (Stake, 1995). The use of a small sample size is acceptable as the sample size allowed the researcher to form relationships with each participant that resulted in greater in-depth analysis leading to a saturation of data (Bogdan & Biklen, 2007; Crouch & McKenzie, 2006; Stake, 1995). Following this guideline, the multiple case study on disciplinary literacy included a sample size of three participants. An invitation to participate in the study was sent to eight potential participants teaching at the selected site (Appendix C). These initial eight potential participants were selected through purposive sampling. Sampling was purposive as specific criteria that included current teaching positions, certifications, and employment at the selected site were used to identify teachers for recruitment.

Three responses were received from the initial recruitment e-mail. In the week following the three responses, the researcher scheduled individual meetings at the site with each potential participant. The researcher explained the study and provided the overview of the study contained within the informed consent document. Potential participants were given the opportunity to ask questions about the study and participation in the study.
Following the recruitment and screening of potential participants to ensure alignment with criteria and research goals, the three potential participants were selected as the final participants (Yin, 2014). Criteria for selection included teachers who were certified or highly qualified in teaching science and currently teaching middle school science. Additionally, the participants represented teachers with varied levels and types of experiences who were teaching different grade levels of science. The researcher met in person with each participant to obtain informed consent (Appendix D).

The selection of participants aligned with recommendations of Shulman (1987) when investigating PCK. Shulman (1987) described variations in the development of PCK based on knowledge and experiences. Therefore, selection of the three participants or cases focused on the inclusion of a variety of background and years of teaching experience. Three educators were willing to participate in the study, cases therefore represented educators with more than four years of science teaching experience, educators with less than four years of teaching experience, and educators who have taught different subjects or grade levels. The selection of diverse participants aided in providing differing perspectives that were cross-analyzed as part of the multiple case study approach.

Ethical Issues/Permissions

Research design must consider ethical issues and obligations that can threaten participant well-being and credibility of results. The researcher was responsible for following all university recommendations and guidelines and obtained IRB approval (Appendix B). Informed consent was obtained from all participants, including permission for recording, through forms shown in Appendix C. Participants were informed and protected throughout research. Researcher role,
positionality, and bias was acknowledged and minimized, especially as the design relied on consistent and ongoing interpretations of observations, experiences, and other data (Stake, 1995).

While institutional guidelines aided in establishing the role of researcher responsibility, the researcher role within the study was also defined (Stake, 1995). Stake (1995) placed selection of researcher role as an ethical choice that may take the form of researcher, scientist, evaluator, therapist, or other possible roles. The role of the researcher may be dictated by the contexts of the case study but should be what Stake (1995) called "an honest choice" (p. 103). In the context of the proposed study, the role of the researcher was that of researcher without additional responsibilities or expectations.

Furthermore, the role of the researcher must not harm participants (Bogdan & Biklen, 2007). The researcher assumed a role that built rapport with participants in a friendly, professional manner. The consideration of participant actions and processes were assumed by the researcher to be genuine and therefore were not to be judged outside of the application of theory and literature on PCK and literacy instruction (NGACBP & CCSSO, 2010; NGSS Lead States, 2013; NRC, 2012; Shanahan & Shanahan, 2008, 2015; Shulman, 1986, 1987). Interviews, observations, and document reviews were conducted with respect to participant routines and classroom procedures to minimize disruptions and avoid harming participants through negative interactions and impacts on classroom instruction (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

The study used the qualitative case study methodology and was non-experimental. The study focused on actions, behaviors and cognitive processes of educators. Permission was obtained from the school district and school selected as the research site as well as from all participants (Appendix A). Confidentiality of the site and participants was maintained throughout
data collection and reporting. All necessary and reasonable efforts were made to collect data with minimal disruptions to participants. Participants were given an overview of procedures and informed consent was gathered from participants.

Data collection, analyses, and interpretations by the researcher must be sensitive to what is known and what is unknown (Stake, 1995). Simultaneously, the researcher should be continually making observations and interpretations that uncover and test information over time (Stake, 1995; Yin, 2014). The continual process of interpretation required patience and skepticism (Stake, 1995). Initial observations and interpretations were not assumed by the researcher to be correct or accurate without further support. Skepticism applied to interpretations led the researcher in gathering additional data to support and revise interpretations respectful of the contexts of the case (Stake, 1995). Verifying interpretations with sensitivity aided the researcher in not exaggerating or overstating claims based on interpretations (Stake, 1995).

Stake (1995) posited that one can assume a position of "relativity, contextuality, and constructivism without believing that all views are of equal merit" (p. 103). However, these views may be treated similarly due to contexts or philosophies guiding social interactions. In case study research, Stake (1995) claimed that relativity should be the predominant paradigm and was followed by the researcher in this study. Stake's (1995) position on relativity justified the nature of case study research based on understanding the individuality of each case. The researcher avoided applying predetermined constructs of reality to preserve the uniqueness of each case and avoided subjugating data through application of biases. The conscious abandonment of neutrality in favor of philosophies of reality that endanger the true meanings within a case constitutes an ethical choice (Stake, 1995).
Data Sources

Stake (1995) and Yin (2014) recommended the use of multiple and varied data sources to support qualitative case study research. Data sources used in this study followed the guideline for varied data sources. Data sources in the study included interviews, observations, and document reviews. Each data source represented perspectives that informed the researcher about the planning for, implementation of, and reflection on disciplinary literacy instruction. The use of varied data sources strengthened the transferability of the study findings (Stake, 1995; Yin, 2014).

Interview data source. The first data source was interviews. Interviews were used in two primary ways throughout the study. First, participants were interviewed prior to observations to provide the researcher with a context for the observation. Participants explained reasoning for and expectations of lessons that would be observed. The second use of interviews centered on critical incidents from observations identified by the researcher. The critical incidents represented actions or situations that required further explanation to understand reasoning or processes that supported teacher actions. Interviews provided insight into participant thought processes that supported the observed actions (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

The use of interviews in qualitative case study research is supported by Bogdan and Biklen (2007), Stake (1995), and Yin (2014). Yin (2014) presented the case study interviews as a "guided conversation" (p. 110) rather than a form of interrogation or questioning. Prolonged case study interviews completed over multiple sittings will be completed as part of the proposed study (Yin, 2014). Interviews will include gathering data on experiences and components of PCK related to disciplinary literacy instruction. As interpretations are made and conclusions drawn, interviews may be used to corroborate researcher ideas or hypotheses (Stake, 1995; Yin, 2014).
Permission was granted by participants for the recording of interviews. Interviews were then transcribed verbatim for future analysis. When recording interviews, the researcher and participants appeared comfortable with the use of recording technology to avoid impacting the data collection process. Recording of interviews did not replace the need for the researcher to be attentive during the interview, but verbatim transcription provided a complete account of the interview that can enhance analysis and interpretation (Stake, 1995; Yin, 2014).

Interviews were both advantageous for and critical in the collection of data. Interviews provided a means of collecting data on participant thinking or logic that preceded instructional actions. The use of interviews were private conversations that had the advantage of one-on-one interactions between the researcher and participant (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). Interviews were critical in allowing the researcher to probe the thought processes of participants to explain the observed actions and lesson plans presented for document review. The use of interviews was critical for uncovering the invisible processing of participants that resulted in the visible, observed actions in the classroom. Interviews were the least intrusive manner for gathering critical data that could not be gained through observations or document reviews.

The disadvantages of using interviews as data sources include the requirement of time, need for participants to be comfortable with the researcher, and participant willingness to share true perceptions (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). First, interviews require a commitment of time outside of participants’ typical duties. Unlike observations, which take place during participants’ normal activity, and document reviews, which are completed by the researcher independent of participant presence, interviews often require participants to sit with the researcher. Secondly, the researcher must develop a relationship with participants that allows participants to feel comfortable in answering questions and sharing data. Finally, an extension of
the participants’ feelings of comfort is necessary for participants to share their thoughts rather than what they perceive to be the expected answers (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

Disadvantages of interviews were addressed through the building of rapport with participants that allowed for a perceived environment of comfortable professionalism and meeting times that were convenient to the participants’ schedules (Bogdan & Biklen, 2007). Additionally, the use of a semi-structured interview approach recommended by Yin (2014) created a conversational rather than an interrogational atmosphere. This atmosphere encouraged participants to share. The maximum length of interviews was 30 minutes to avoid intruding on participant routines. Confidentiality of collected data and anonymity of reported findings encouraged participants to share their thinking ((Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). The use of critical incidents as the basis of interviews allowed the researcher to focus the conversation on what was observed, which also provided a level of comfort for participants in explaining what had been observed. The establishment of rapport and comfortable environments and interview times convenient for the participants were used to overcome the disadvantages of interviews.

**Observation data collection.** The problem of the study focused on the implementation of disciplinary literacy instruction in science classrooms. Observations are a key component of qualitative case study research in collecting data on participant actions (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). Observations have minimal impacts on participant time and routines. Observations can vary in length and can therefore be planned to meet the constraints of the site or the phenomenon being studied. At the potential research site, class length is 57 minutes and meets daily Monday through Friday. Observations were scheduled for one class period at a time.
Observational data were gathered through direct observation as an external observer in the classroom. The researcher did not have an active role in the teaching and learning process. Observations were advantageous in allowing the researcher access to authentic teaching environments. Observations in the classroom during instruction place the data collection in an authentic setting that provided the researcher with contexts that aided in description and interpretation (Stake, 1995; Yin, 2014). Throughout the process of observation, the researcher maintained impartiality with a focus on the research topic (Yin, 2014).

The study included observations of disciplinary literacy embedded in the instruction of a science-certified educator and utilized a protocol to guide recording of notes as discussed in a later section. Observations will be scheduled to minimize impacts on participants. While the addition of the researcher in the classroom may constitute a distraction and therefore a disadvantage of observations, the recurrent presence of the researcher resulted in the participating teachers and their students accepting the presence and engaging in what appeared to be typical classroom behaviors.

Disadvantages of the study include limitation of data to observed actions. When completing observations on classroom implementation of disciplinary literacy instruction, the researcher can record what is happening in the classroom. However, this data does not provide reasoning for these actions (Shulman, 1986, 1987; Stake, 1995; Yin, 2014). To account for the lack of reasoning presented in observations, observations were paired with interviews. The pairing of interviews and observations allowed the researcher to investigate participant reasoning as related to identified actions or critical incidents. The use of interviews with observations strengthens the data gathered through each approach (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).
Additional disadvantages of observations include gaps in recorded notes or attempts to analyze or interpret beyond the observed data (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). To address these disadvantages, the researcher wrote a description of the observation within 30-minutes of the conclusion of the observation. The written description included as much descriptive detail as possible and was limited to recording actual observations and not interpretation (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). The written summaries were used to enhance notes taken during the observation and provide a narrative of the observation that could be analyzed later. The written account was used to minimize gaps in researcher notes (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

Observations were critical data collection sources within the study. Interviews and document reviews provided teacher perceptions and plans but did not communicate classroom actions of the teachers. Observations on their own provided data on classroom implementation without the context of teacher intent and through processes. Consistent with the recommendations of Stake (1995) and Yin (2014), observations provided one source of data. When combined with other data sources, observations contribute to a more complete understanding of the problem of disciplinary literacy implementation being studied (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

**Document review data collection.** Documents and artifacts can provide meaningful sources of data (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). Documents that included lesson plans and teacher created resources were used in data collection. Lesson plans and planning documents were shared with the researcher to provide information about the planning and structuring of learning opportunities. Resources provided by the teacher, such as hand-outs, organizers, and articles were also shared for analysis. The documents provided data on planning
and on resources that supported implementation of disciplinary literacy instruction in science (Houseal et al., 2016; Stake, 1995; Yin, 2014).

One disadvantage of planning documents is that these documents represent teacher intentions, but do not reflect actual implementation. When paired with data from observations of implementation, lesson plan documents can demonstrate intent of lesson objectives and planned activities. Lesson planning documents provide insight into practices and processes used by participating educators in instruction of disciplinary literacy, thus showing possible content, pedagogy, and PCK. Teacher resources, such as textbooks and other materials provided by the district or located by the teachers, also aided the researcher in understanding sources of content and pedagogical knowledge incorporated into PCK (Shulman, 1986, 1987).

Resources for document review are critical to the study of disciplinary literacy implementation in science classrooms. Lesson plan documents provide insight into intended pedagogy and activities for communicating and structuring engagement with science and literacy learning. Student resources can be collected as a source of data on implementation of disciplinary literacy and educator instructional decisions stemming from PCK. Documents, including worksheets, texts, notes, and strategies can provide insight into actions that transform disciplinary literacy through PCK (Shulman, 1986, 1987). Teacher use of documents can be related to observed instruction and intentions communicated through interviews (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

**Research Protocols/Instrumentation**

Stake (1995) recommended planning and organization to facilitate data collection and tracking. This study followed a plan that utilized varied protocols and instrumentation. Methods of data collection included observations, interviews, and document reviews. Each of these
methods was guided using organizers and protocols (Stake, 1995). Data collection was completed over the course of nine weeks.

**Interview protocol.** Interviews were semi-structured and guided by an interview protocol (Appendix E). The work of Park et al. (2011) formed the foundation for the interview question protocol. Using the theory of PCK with a focus on disciplinary literacy, the interview question protocol presented in Park et al. (2011) was adapted for use in the current study. Modifications of the protocol were necessary to focus the interview questions from a broader view of PCK for science instruction to a specific focus on disciplinary literacy. The modified protocol was presented to Dr. Soonhye Park and permission to use the modified protocol was obtained from Dr. Park (Appendix F). The protocol included a list of questions that could be sequenced in interviews. Drawing from the work of Park et al. (2011) addressing PCK and the literature on literacy instruction, the protocol of possible research questions was developed. These questions bridge the theory of PCK with aspects of disciplinary literacy and science practices used in classroom instruction. Since the interviews were semi-structured, the researcher also formulated and asked probing questions to address data that arose during the interview. The protocol was used to facilitate the flow of the interview within time constraints and to maintain the focus on the topic of the case (Stake, 1995). Questions contained in the protocol focused on educator actions related to disciplinary literacy instruction in planning, implementation, assessment and reflection on implementation.

**Observation protocol.** The observation protocol was structured to maintain focus on the issue of literacy instruction and facilitate a descriptive record for future analysis (Stake, 1995; Yin, 2014). Drawing from the theory of PCK and literature on literacy instruction, observations initially focused on the pedagogical knowledge and content knowledge of the participating
educators as related to disciplinary literacy (NGACBP & CCSSO, 2010; NGSS Lead States, 2013; NRC, 2012; Park et al., 2011; Shanahan & Shanahan, 2008, 2015; Shulman, 1986, 1987). During observations, critical incidents were identified. Critical incidents were educator actions that prompted questions or interest of the researcher. These incidents informed interview questions to further probe and understand educator understanding and reasoning that resulted in the observed actions. Field notes were written as appropriate during the observation with descriptive notes elaborated immediately following the observation. Notes were written as close to observations as possible and no later than 30-minutes after the observation to capture the true descriptions of the observations (Stake, 1995; Yin, 2014). An observation protocol was used to organize these notes (Appendix G) and fits with Stake’s (1995) recommendation for planned and organized approaches to data collection.

**Document review protocol.** Documents, such as lesson plans and student resources provided by the educator, provided information that supports the case. As in the use of observation and interview data, a protocol aided in describing and interpreting the document in relation to the research questions (Appendix H). Review of documents were aligned with the research questions of the case study (Stake, 1995). In each of these reviews, the protocol had sections to guide the description and later interpretation of the role of the document in the reasoning and action phases of pedagogy, content, and PCK (Shulman, 1987; Stake, 1995; Yin, 2014).

**Reliability and validity of protocols.** All protocols were developed based on the theory of PCK and the literature on literacy instruction (NGACBP & CCSSO, 2010; NGSS Lead States, 2013; NRC, 2012; Shanahan & Shanahan, 2008, 2015; Shulman, 1986, 1987). Prior to application in the field, interview, observation, and document review protocols were presented to
dissertation committee members for expert review. The committee included literacy and science experts who examined and provided feedback to verify face and construct validity (Bogdan & Biklen, 2007). Committee methodologists verified the alignment of protocols with the qualitative case study methods (Stake, 1995; Yin, 2014). The committee of experts agreed that the protocols were reliable and valid for use in the study.

**Data Collection Procedures**

Data collection procedures included the development of protocols, data collection through interview, observation, and document review, and analysis of data. As shown in Figure 1, the data collection was guided by the developed protocols and included an iterative cycle of interviews and observations followed by coding and analyses of data. After each interview and observation, the researcher completed member checks with participants to guide the descriptive process. Member checks were also used during analyses of data to aid interpretation and conclusions (Bogdan & Biklen, 2007).

**Prior to data collection.** Prior to submitting an application to the IRB (Appendix B), site permissions (Appendix A) were obtained as required. Approval was obtained from the IRB before recruitment of participants and data collection commenced. Immediately upon receiving IRB approval, the researcher sent an e-mail (Appendix C) to recruit interested teachers for participant in the study. After receiving interest from potential participants, the researcher scheduled times to meet with each potential participant. During the meetings, the researcher further explained the study and answered questions from each potential participant. Once participants were selected and agreed to participate in the study, the researcher met with each participant and gathered informed consent. Protocols were developed as described earlier and aligned to the research questions of the study.
During data collection. Data were collected through interviews, observations, and document reviews consistent with the qualitative case study methods outlined by Stake (1995) and Yin (2014). A total of nine semi-structured interviews per participant were completed prior to observations to gain insight on the planned actions and intended outcomes of instruction in the observed lessons. Data were also collected from three interviews with each participant following observations and centered on critical incidents identified by the researcher. These critical incidents were occurrences that needed clarification or probing to further understanding of participant decision-making and actions as related to PCK and disciplinary literacy. Observation data was gathered through 15 direct observations of each participant. Lesson plan documents were reviewed for each of the 15 lessons along with resources provided to students during select
lessons. The three participants were identified as Kaitlyn, Melanie, and Debra as described in Chapter Four. These same pseudonyms are used for consistency and simplicity of data reporting.

Table 1

*Initial Code List for Study of Disciplinary Literacy Instruction in Science*

<table>
<thead>
<tr>
<th>Self-regulation Activity</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Content</td>
<td>SC</td>
<td>Disciplinary content information, including required factual knowledge and skills for engaging in scientific thinking and tasks (Moje, 2007, 2008; Shulman, 1987).</td>
</tr>
<tr>
<td>Reading</td>
<td>RD</td>
<td>Reading is used to engage students in learning content to prompt questioning and inquiry into content (Rupley, 2010).</td>
</tr>
<tr>
<td>Writing</td>
<td>WR</td>
<td>Writing is used to construct knowledge or to respond to learning (Yore, 2004).</td>
</tr>
<tr>
<td>Speaking &amp; Listening</td>
<td>SL</td>
<td>Discourse is used to build knowledge or facilitate learning (Michaels et al., 2008).</td>
</tr>
<tr>
<td>Knowledge</td>
<td>KN</td>
<td>Use of general knowledge about science or literacy (Moje, 2007, 2008; Shulman, 1987).</td>
</tr>
<tr>
<td>Questioning and Problem Identification</td>
<td>QP</td>
<td>Practice of questioning and identifying problems (NRC, 2012; NGSS Lead States, 2013)</td>
</tr>
<tr>
<td>Modeling</td>
<td>MD</td>
<td>Practice of model development and use (NRC, 2012; NGSS Lead States, 2013)</td>
</tr>
<tr>
<td>Investigating</td>
<td>IV</td>
<td>Practice of investigating, including planning and carrying out procedures (NRC, 2012; NGSS Lead States, 2013)</td>
</tr>
<tr>
<td>Using Data</td>
<td>DA</td>
<td>Practice of using data through analysis, interpretation, and application (NRC, 2012; NGSS Lead States, 2013)</td>
</tr>
<tr>
<td>Mathematics and Computational Thinking</td>
<td>MCT</td>
<td>Practice of using thinking or logical reasoning through the application of mathematics (NRC, 2012; NGSS Lead States, 2013)</td>
</tr>
<tr>
<td>Explanations and Solutions</td>
<td>ES</td>
<td>Practice of explaining phenomena or developing solutions to problems (NRC, 2012; NGSS Lead States, 2013)</td>
</tr>
<tr>
<td>Argument from Evidence</td>
<td>AE</td>
<td>Practice of stating and defending a claim based on reasoning and supporting evidence (NRC, 2012; NGSS Lead States, 2013)</td>
</tr>
<tr>
<td>Information</td>
<td>INFO</td>
<td>Practice of gathering, evaluating, and communicating information about a topic or problem (NRC, 2012; NGSS Lead States, 2013)</td>
</tr>
<tr>
<td>Skills</td>
<td>SK</td>
<td>Use of skills in engaging in science or literacy practices (Moje, 2007, 2008; Shulman, 1987).</td>
</tr>
<tr>
<td>Teacher Initiated</td>
<td>TI</td>
<td>Behaviors or learning activities initiated by the teacher.</td>
</tr>
<tr>
<td>Student Initiated</td>
<td>SI</td>
<td>Behaviors or learning activities initiated by the student(s).</td>
</tr>
<tr>
<td>Independent</td>
<td>ID</td>
<td>Work is completed independently</td>
</tr>
<tr>
<td>Collaborative</td>
<td>CO</td>
<td>Work is completed collaboratively (part of a group)</td>
</tr>
</tbody>
</table>
Data collection commenced one week after obtaining informed consent from the participants. During the first week, initial interviews were completed with all three participants. The initial interviews focused on participant knowledge of literacy and science instruction as well as background experiences related to the instruction of literacy in the science classroom and the NGSS and related instructional shifts (NGSS Lead States, 2013). Pre-observation interviews were completed with Kaitlyn, Melanie, and Debra to preview lessons for observation. Kaitlyn and Melanie were each observed in their classrooms two times during the first week of data collection. Debra was observed in her classroom once during the first week. Review of the observations led to a critical incident being identified for each participant, including Kaitlyn’s use of notebooks in the classroom and Melanie’s assignment of articles and summaries to be completed outside of class.

The second week of data collection included pre-observation interviews with all three participants. In addition to pre-observation interviews, Kaitlyn and Melanie each participated in a post-observation interview to describe the identified critical incidents. One observation of Kaitlyn and one observation of Debra were completed in their classrooms. Two observations of Melanie were completed in her classroom. The critical incident of modeling used in Melanie’s instruction was identified based on the reviews of the observations in Melanie’s classroom. While this critical incident was identified, more observation was required prior to a follow-up interview about the use of modeling.

There were no post-observation interviews completed during the third week of data collection. The data collection in Week 3 included three pre-observation interviews. One observation was completed for each participant. Based on reviews of the observations, a critical incident in the interactions of different groups in Debra’s classroom formed the critical incident.
In this critical incident, different groups and classes responded differently to Debra’s instruction and therefore prompted Debra to alter her approaches to instruction.

A post-observation interview on the critical incident identified from the observations of Debra was completed during Week 4. The fourth week also included pre-observation interviews with all three participants. During this week, two observations of Debra and Kaitlyn and one observation of Melanie were completed in their classrooms. Critical incidents were identified from the observations, including the use of class discourse by Kaitlyn and Melanie and Debra’s use of word study.

Week 5 of data collection included pre-observation interviews with all three participants. Post-observation interviews were completed with all three participants to explore the critical incidents identified in the fourth week of observations. Similar to the prior week, two observations were completed for Kaitlyn and Debra and one observation was completed for Melanie in their classrooms. Single classroom observations of Melanie for the past two weeks were due to scheduling conflicts, such as team field trips, assessments, and reward days based on the school behavior system that impacted the timing of science instruction. Critical incidents identified in the observations included Kaitlyn’s restructuring of a laboratory activity, Melanie’s use of groups, and Debra’s integration of individual and group work within the observed lessons.

For Week 6, data collection included pre-observation interviews with all three participants. Post-observation interviews were completed with each participant. Two observations were completed for each participant. There were no critical incidents identified from the observations completed in week six.

In Week 7, pre-observation interviews were completed with all three participants. There were no post-observation interviews in Week 7, but classroom observations were completed.
Two observations of Kaitlyn and Melanie were completed in their classrooms. Three observations of Debra were completed in her classroom. One critical incident spanned the observations of all three participants. The critical incident centered on the development and use of models in each classroom.

Winter break for teachers and students at the site occurred between data collection Week 7 and 8. Upon returning from break, data collection with participants continued. During Week 8, pre-observation interviews were completed. Due to returning from break, scheduling conflicts did not allow for post-observation interviews. Two observations of each participant were completed in their classrooms during data collection Week 8.

Week 9 was the final week of data collection. This week included the conclusion of the units of study that had been observed since the first week of data collection. Week 9 corresponded to the end of the grading term and upcoming preparation for exams. During the ninth week of data collection, pre-observation interviews were completed with all three participants. One observation of Kaitlyn was completed in her classroom as well as two observations of Melanie and Debra in their classrooms. Post-observation interviews for all three participants were completed to focus on the previously identified critical incident of modeling as well as the current critical incidents of varied literacy instructional strategies used over the last two weeks of observations.

After data collection. Data collection lasted nine weeks. The data collection lasted for the duration of one instructional unit implemented by each of the three participants. Data collected at the conclusion of the instructional unit and provided a saturation of data (Bogdan & Biklen, 2007). Both during and after data collection, all collected data was confidential. Limited digital or electronic data were collected outside of recordings. Digital or electronic data was
stored on secure drives that were password protected. Paper copies of documents, notes, and other materials were secured in a locked file cabinet. Audio and video recordings were stored on password protected drives that were only accessible to the researcher. Files will be maintained until after successful completion of the dissertation effort and any related submissions for publication have been completed. The estimated date that recordings will be destroyed is one year after the completion of the study.

**Researcher Positionality**

Researcher positionality is important in identifying potential sources of bias that may impact the study. Therefore, the positionality of the researcher should be stated (Bogdan & Biklen, 2007). The positionality of the researcher includes personal characteristics, experiences, and relationships. The researcher positionality is presented in three sub-sections. The areas of positionality are presented as demographics and affiliations, life experiences, and relationships.

**Demographics and affiliations.** The researcher is a White male science teacher at an urban high school. Due to his current employment status, the researcher placed himself as being in the middle class. The researcher obtained an undergraduate degree in biology and science education and a graduate degree in special education. The researcher earned an education specialist degree in curriculum and instruction while pursuing a doctorate degree. The researcher is a member of the National Science Teacher Association and the state science teacher association. The researcher is also a graduate student member of the American Association for Teaching and Curriculum.

**Life experiences.** Shanahan and Shanahan (2008) proposed a shift in approaches to disciplinary literacy instruction. As a secondary science teacher with 13 years of experience in the formal school setting, the researcher experienced professional development with a focus on
content area literacy instructional strategies but had encountered a lack of supportive
development for disciplinary literacy instruction. In response to this lack of disciplinary literacy
development, the researcher facilitated a professional development experience for science
teachers and literacy coaches using the work of Lent (2015) to initiate discussions about literacy
instruction in science classrooms. The state in which the researcher resides and teaches has
adopted CCSS (NGACBP & CCSSO, 2010) and the NGSS (NGSS Lead States, 2013) which
support authentic practices in the disciplines, including literacy. Adoption of CCSS (NGACBP &
CCSSO, 2010) and NGSS (NGSS Lead States, 2013) standards prompted the researcher's district
of employment to establish goals within district and school improvement plans that focus on
literacy instruction and implementation. National, state, and local literacy and science initiatives
motivated the researcher to investigate disciplinary literacy instruction and development of PCK
to improve disciplinary literacy instruction in science instruction.

In the view of the researcher, disciplinary literacy instruction is authentic to the use of
literacy in the science discipline and PCK can impact instruction based on individual teacher
contexts, understandings, and beliefs. The researcher sought to understand teacher knowledge,
pedagogy, and perceptions that influence literacy instruction in the discipline. The researcher
took the position that varied beliefs, perspectives, and experiences of teachers result in differing
understanding and views of disciplinary literacy by science and literacy educators. Such a view
of disciplinary literacy in science allowed for an emic approach in the collection of data on
internal structures and practices as supported by Shulman's (1986, 1987) theory of PCK. The
researcher also believed that commonalities or themes exist in teacher definitions, understanding,
and professional development needs of teachers.
The processes of the researcher were guided through frequent debriefing sessions with university supervisors and the inclusion of the researcher's reflective commentary in the analysis and reporting of results. The researcher aimed to maintain an unbiased, relative approach to data collection and analysis (Stake, 1995). The position, beliefs, and assumptions of the researcher were expressed as a means of disclosing inherent researcher perspectives (Yin, 2014). While the position of the researcher as a secondary science teacher could potentially be a source of bias, the position helped build relationships that facilitated sharing of information in interviews and access to other materials.

**Relationships.** The researcher formerly taught at the research site. However, he no longer has regular contact with the teachers at the school, including the participants in the study. The researcher had prior professional relationships with two of the participants. The professional relationships occurred as the result of the researcher and participants formerly being members of the same science department at the same school. No social relationships exist between the researcher and the participants.

**Ensuring Trustworthiness and Rigor**

Qualitative case studies can be designed to ensure credibility and rigor of methods and conclusions. Using case study methods as described by Stake (1995) and Yin (2014) represents the use of well-established methods in the process of data collection and analyses. The use of well-established methods will improve the credibility of the research process. The process of gathering data was further supported by the experience of the researcher as a former middle level science educator. This experience provided a familiarity with the structure of middle level science instruction and aided in developing an understanding of the culture of the participants and the overall organization of the site. Development of an understanding allowed connections
between the researcher and participants that led to improved comfort and interactions that enhanced communication and data collection (Stake, 1995; Yin, 2014).

**Credibility and trustworthiness.** Credibility and trustworthiness of data are supported through the use of documented, established methods (Bogdan & Biklen, 2007). Qualitative case study methods were used in the study consistent with the presentation by Stake (1995) and Yin (2014) overviewed the use of qualitative case study methods. This study followed the guidelines for qualitative case study methods presented by Stake (1995) and Yin (2014), which supported the credibility of methods and procedures used in the collection of data. The analysis of data followed the established procedures of Saldaña (2016), Stake (1995), and Yin (2014). The use of established methods provided credible procedures for data collection and analysis.

The background of the researcher as a former middle level science teacher provided a familiarity with the structure of the participants’ institution, curriculum, and schedule. This understanding of the systems impacting participants provided context for understanding the cases being studied (Bogdan & Biklen, 2007). While this understanding may be beneficial in forming relationships to gather data, caution must be taken to minimize researcher preconceptions and bias (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). Researcher awareness of positionality, debriefing with the dissertation committee chair, and the use of triangulation and member checks were used to aid in ensuring credibility (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

As recommended by Stake (1995) and Yin (2014), credibility of data can be improved when collected from multiple sources and varied perspectives. The selection of participants with various backgrounds and experiences allowed for different perspectives and approaches toward the development and implementation of PCK and disciplinary literacy. This study also gathered data from varied sources that included observations, interviews, and document reviews within
each case. Cases were selected to represent science instruction at different grade levels. The three cases were then compared and contrasted in the synthesis of the multiple case studies. The varied perspectives improved interpretations and therefore credibility of the case study (Yin, 2014).

Triangulation is a process used by researchers to bring together data from various sources to enhance credibility and trustworthiness (Bogdan & Biklen, 2007). Different data sources were used in triangulation to clarify the interpretations of information and determination of meaning from participants. Themes developed within each case were triangulated using data gathered from varied sources (Stake, 1995; Yin, 2014). Cross-case synthesis provided data from different cases. The data from different cases were used to triangulate themes to support analysis and conclusions (Stake, 1995; Yin, 2014).

In addition to researcher triangulation of data, member checks allowed participants to provide feedback to the researcher that ensured appropriate description and analysis of data (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). Participants were interviewed about critical incidents identified by the researcher, thus participants provided feedback and checked the researcher identification of identified incidents. Further member checks occurred as the researcher identified themes within each case. Participants reviewed researcher presentation of data to confirm themes generated by the collected data. Consistent with the research of Bogdan and Biklen (2007), Stake (1995), and Yin (2014), member checks ensured credibility and trustworthiness through participant review, feedback on, and verification of researcher ideas.

Credibility and trustworthiness can be strengthened through peer review of research and conclusions (Bogdan & Biklen, 2007; Campbell & Stanley, 1963; Stake, 1995; Yin, 2014). The dissertation committee provided peer review of the research process from design through conclusions. The dissertation committee included science and literacy experts. These experts
were well positioned to review the work and conclusions of the researcher. Feedback from the review strengthened the analysis and resulting conclusions based on the research findings.

Conclusions from the current study were compared to current literature in science and literacy education. The comparison of current findings to research supports the credibility and trustworthiness of the study (Bogdan & Biklen, 2007). Comparison to prior research provided identification of findings that align with or diverge from current literature. The comparison was then used to support current interpretations and to determine alternate interpretations consistent with prior findings (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

Protocols were developed for use in interviews, observations, and document reviews. To ensure trustworthiness and credibility of these instruments, the protocols were submitted to the doctoral dissertation committee for expert review (Bogdan & Biklen, 2007). Experts in science and literacy instruction reviewed the protocols for face and construct validity (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). The methodologist reviewed the protocols for alignment with qualitative case study methods (Stake, 1995; Yin, 2014). Upon completion of the expert review, the protocols were approved for use in the study.

Yin (2014) stated that lack of internal validity is predominantly associated in case study research with explanatory case design but should be considered whenever inferences are made by the researcher. The research considered multiple explanations for events and actions. The evidence gathered from different sources was analyzed to check for the "convergence" (Yin, 2014, p. 47) of data from multiple sources. Considering all possible explanations and converging data strengthened internal validity (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014).

External validity can be supported through the use of theory in case study research. The application of theory allows for "analytic generalization" (Yin, 2014, p. 40) that uses case study
findings to support or reject the theory utilized in the investigation of the case. Findings from the case study were used to inform new developments of theory (Yin, 2014). The application of learning from the case study to theory, use of theory, or development of theory represented a level of transferability from the study. While not generalizing to a broad population or context, information can be transferred to research and understanding the use of theory in specific types of cases.

**Transferability.** Qualitative methods of case study research are limited in generalizability. Even with limited generalizability, transferability of findings by the reader can be maintained through the provision of thick descriptions in research findings (Stake, 1995; Yin, 2014). Results of the study included detailed, thick descriptions of educator actions and processes resulting in the implementation of disciplinary literacy instruction in the science classroom. The thick descriptions provided information on the context of the study that helps readers understand the conditions being researched. With an understanding of the current contexts, readers can determine the transferability of findings beyond the stated research environments. Descriptions presented in this study enable transferability of findings by readers (Stake, 1995; Yin, 2014).

The use of cross-case analysis as described by Yin (2014) allowed for comparison of the three studied cases. The descriptions of the research aided in providing context and understanding of disciplinary literacy as implemented in the classroom, thus assisting in addressing the need for research beyond conceptualizations of disciplinary literacy (Faggella-Luby et al., 2012; Fang & Coatoam, 2013; Shanahan & Shanahan, 2012). The use of cross-case analysis broadened the research from singular cases and demonstrated wider themes that the
reader may be able to transfer or apply in other settings (Bogdan & Biklen, 2007). Drawing from multiple cases increases the transferability of the research (Bogdan & Biklen, 2007; Yin, 2014).

**Confirmability.** Reliability in case study research depends on the ability of other researchers to reach the same interpretations and conclusions when analyzing the same case (Yin, 2014). Confirmability of results was achieved through triangulation of data and member checking to verify themes. Triangulation through using multiple sources of data and multiple methods to compare data supported the credibility and reliability of the study and the results (Stake, 1995; Yin, 2014). Consistent with recommendations of Stake (1995) and Yin (2014), this study included varied perspectives through the inclusion of multiple science educators with different experiences.

**Data Analysis Techniques**

Data analysis was ongoing throughout the data collection process to inform questions, observations, and interviews during the data collection processes (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). Data analyses and interpretations continued beyond the collection of data. As interpretations and conclusions were developed, participants were asked to review researcher conclusions for accuracy and alignment with participant statements and intentions (Bogdan & Biklen, 2007; Stake, 1995; Yin, 2014). After each case had been analyzed, cross-case analyses were then completed to compare and contrast educator implementation of disciplinary literacy and related PCK constructs (Yin, 2014).

Yin (2014) included explanation building and cross-case synthesis as two techniques used in analyzing case study data. Explanation of the case and the topic studied in the case was presented in a narrative form that includes description and interpretations of how and why acts occur within the case. The use of explanation building was applied in the proposed case study as
the study applied the theory of PCK to explain how and why disciplinary literacy instruction was implemented in the science classroom (Shulman, 1987; Yin, 2014). Data were analyzed with the intent of explaining PCK and disciplinary literacy.

The analysis was built from developing explanations and included a comparison of the three cases. The PCK and implementation of disciplinary literacy instruction by the three selected science educators were treated as separate cases. Data collection and analysis for these cases was completed and then synthesized. The analysis and comparison of multiple cases informed research that gathered evidence through methods that broaden the application or transferability of the study (Yin, 2014). In the study, cross-case synthesis was applied to better understand differing approaches to disciplinary literacy in a manner that analyzes PCK and implemented instruction that described and explained themes generated from the three cases.

Data analysis is important in understanding the case and should be approached in an effort to interpret what is represented relative to the case and the research topic. Yin (2014) suggested initiating analysis through analyzing questions, beginning with questions that have a smaller scope and progressing to questions that have a larger scope. Data were strengthened and simplified through condensation described by Miles, Huberman, and Saldaña (2014). This process of coding and categorization of findings is represented in Figure 2 (used with permission as documented in Appendix I). Data, including interpretations or tentative conclusions with supporting evidence, were presented through passages of descriptive text. Visual representations of connections between data revealed through condensation were used to strengthen understanding of data and follow the form of matrices or other graphic representations (Miles et al., 2014; Stake, 1995; Yin, 2014). Conclusions from data condensation and display informed themes and conclusions, which lead to further data collection (Miles et al., 2014).
Data display and reduction was assisted through card sorts and categorization of data beginning with the initial code list applied to interview, observation, and document review data. Excerpts of coded data were sorted using a card sort of data. Using the card sort, patterns of codes and connections between coded excerpts of data were used to develop new codes, identify themes, and categorize coded excerpts within the data. Interactive visual displays of data allowed for further analysis by the researcher. Each case was analyzed separately and then compared and contrasted as described in Yin’s (2014) methods of multiple case studies.

**Data coding.** Coding of data began with what Saldaña (2016) referred to as “pre-coding” (p. 20) when the researcher marked passages of notes or transcriptions from data collection as noteworthy areas of to focus on during coding applications. These marked passages represented sections that were highlighted in analytic memos written by the researcher to distinguish events or concepts and serve as reminders to self throughout analyses (Bogdan & Biklen, 2007; Saldaña, 2016). Coding of data for analysis occurred through multiple cycles. Types of codes varied as analysis and coding progressed. Initial cycles of coding drew from the pre-set list of...
“descriptive” and “structural” (Saldaña, 2016, p. 73) codes. These codes were used to summarize the main idea of a section of data to allow grouping of data with topical connections and relate sections of data to the overarching research question or sub-questions. In vivo coding was then applied by using words or phrases drawn directly from participants to code and organize sections of data (Saldaña, 2016).

Subsequent iterations of coding were used to further analyze data. “Eclectic coding” (Saldaña, 2016, p. 74) with the use of analytic memos, descriptive, structural, and in vivo codes that used participants’ words or ideas to label data brought together and connected information into themes that form a more complete narrative of the data. The use of eclectic coding was aided through analysis of patterns that can be used to group similar codes in the process of “pattern coding” (Saldaña, 2016, p. 74). “Focused coding” (Saldaña, 2016, p. 74) deepened understanding of in vivo codes developed during initial analyses to group and identify common and significant ideas, themes, or topics generated from participants. Themes were identified that fit with Creswell’s (2014) outcomes of analyses that include what fits with current literature, commonalities in data that differ from current literature, and outliers that are significant due to being unusual and standing out from both the literature and other collected data. The use of multiple code types incorporated varied data and assisted the researcher in maintaining focus on participant actions and contributions (Bogdan & Biklen, 2007; Creswell, 2014; Saldaña, 2016; Yin, 2014). Codes were compiled and organized in a code list or book as described by Saldaña (2016) and DeWalt and DeWalt (2011).

Consistent with the process presented by Miles et al. (2014) and Yin (2014), data were condensed through coding and categorization and represented visually in matrices, organizers, flow charts, and tables that aided in identifying patterns and connections between data that
impact the research question being investigated. The creation of connections to be demonstrated graphically were made through analyzing data and using spreadsheet and word processing software. Coded excerpts were manipulated within the software and included ordering of data, whether chronologically or by theme or code, to represent processes (Yin, 2014). When considering disciplinary literacy instruction PCK, organizing and ordering data illustrated connections between content knowledge, pedagogical knowledge, and PCK that was expressed in the disciplinary literacy instruction observed through data collection and analysis.

Theoretical positions. Yin (2014) suggested different strategies for analyzing data. The use of theoretical position informed analysis of data and provided opportunities for "analytic generalizations" (Yin, 2014, p. 40). Relying on the theory of PCK aided the researcher in focusing on the components of PCK that are tied to instruction, thus allowing for descriptions of instruction and connections that informed disciplinary literacy instruction in the science discipline (Shulman, 1987; Yin, 2014). The use of theory was used to further descriptions of mental processes and actions of implementation as well as allowing for consideration of other possible explanations for collected data (Yin, 2014).

When attempting to describe a case, the use of theory was used to interpret actions. The constructs of Shulman's (1986, 1987) theory of PCK were applied when studying the knowledge, reasoning, and actions of educators in applying disciplinary literacy instruction in science classes. The use of theory informs questions, analysis, and reporting of data in descriptive case studies as descriptions drew from established theory and data analysis to illustrate the case and associated learning. Overall descriptions were enhanced when guided by theory that informed case study design, data collection, and analysis (Yin, 2014).
The theoretical framework used to guide the case study provided a means of analyzing and explaining the data collected in the case study. PCK includes components of content knowledge and pedagogical knowledge, which were used to interpret and explain data related to disciplinary literacy instruction. However, alternate explanations of teacher knowledge and behaviors were considered (Yin, 2014). Following this recommendation, the researcher applied PCK as described by Shulman (1987, 2015) as well as PCK from the science education perspective as outlined by Grossman (1990), Magnusson et al. (1999), and Park and Oliver (2008). The consideration of different explanations strengthened the analysis and conclusions of collected data (Yin, 2014).

**Chapter Summary**

The qualitative research paradigm was selected for the study due to the focus of exploring and describing educator actions in developing disciplinary literacy PCK and implementing disciplinary literacy instruction (Shulman, 1983, 1986, 1987; Stake, 1995; Yin, 2014). Multiple qualitative case study qualitative methodology was used to determine the perceptions, understandings, and implementation of disciplinary literacy PCK of science educators teaching science courses in an urban, middle level school in the United States. A relativist, emic approach was used to collect data through observations, semi-structured interviews, and document reviews. Themes generated from each case were analyzed and then synthesized through comparisons and contrasts focused on disciplinary literacy PCK and implementation in science instruction. Precautions were taken to ensure the impartiality of data collection through member checking and triangulation (Bogdan & Biklen, 2007; Yin, 2014). The well-being of all participants was addressed by obtaining IRB approval and informed consent from each participant as well as through researcher actions that minimized impacts to the participants.
Site selection for the proposed study aligned with Stake's (1995) recommendation to be accessible to the researcher and Yin's (2014) guidelines to carefully screen for the ability of the case to match research goals. The site was considered a typical example of middle level school structure in the United States, which can enhance the transferability of interpretations and conclusions resulting from the study (Stake, 1995). Participants were purposely selected from a convenience sample based on criteria that include proper certifications for teaching middle level science within a site focused on improving literacy instruction. These criteria aligned with research goals and expectations by focusing on science teachers at the middle school level. The selection of such cases was relevant to the research effort and to the district literacy goals.

Prior to data collection, IRB approval of the study was obtained. Informed consent obtained from participants and permission from selected site was essential and was secured by the researcher before beginning data collection. Measures to protect the confidentiality and well-being of participants was used throughout the duration of the study and reporting of results. The researcher made decisions based on ethics that allowed interpretation of data with minimal impacts of researcher bias (Stake, 1995). Data were confidential and anonymous with all identifiers removed prior to reporting.

Yin (2014) suggested the creation of a database that includes varied data sources that can be analyzed and applied to the research questions. During data collection, observation, interview, and document review data sources were compiled into such a database that provided data for analysis from different sources and perspectives. The use of protocols guided the data collection. Interview questions were adapted from the work of Park et al. (2011) and observation and document review protocols were constructed based on theory and were reviewed by doctoral
dissertation committee members prior to use in the study. The use of protocols guided questions and observations to ensure alignment of data collected with the research questions.

Procedures for data collection, including prior to, during, and after collection were described. Procedures were consistent with the selected methodology and flowed from the purpose, problem, and research questions. The researcher’s positionality as a science teacher and former middle school teacher was stated as well as prior professional interactions with two participants. The acknowledgement of positionality can aid in limiting bias when interpreting and presenting findings (Bogdan & Biklen, 2007). Methods for ensuring trustworthiness and rigor of qualitative research were presented prior to an overview of data analysis.

The analyses of case study data were consistent with Yin’s (2014) recommendation that analysis progress from research questions of smaller scope to those of larger scope. Data was coded by the researcher to represent key ideas and themes generated by initial analysis of data and refined through subsequent iterations of coding (Saldaña, 2016). The theory of PCK was applied to support analysis and cross-case synthesis of data from observations, interviews, and document review of data from the 3 cases (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1987; Yin, 2014).

Chapter 4 will present findings from the study. After a description of participants, the findings for each participant will be presented as within-case analyses. Following within-case analyses, findings from cross-case analyses will be presented. Analysis of findings will be presented as ideas flowed from each research question.
Chapter 4: Data Analysis and Results

Disciplinary literacy represents a re-emphasis of literacy in science instruction framed by Moje (2008) and Shanahan and Shanahan (2008). Additional research is necessary to aid in moving from conceptualizations of disciplinary literacy to classroom implementation as recommended by Fang and Coatoam (2013). The purpose of this qualitative case study was to explore the disciplinary literacy instruction implemented in middle level science classrooms in an urban middle school in the United States. The study aims to describe conditions that foster or present obstacles to the implementation of disciplinary literacy in order to answer the following overarching research question: What do science educators in an urban middle school know about and do to implement disciplinary literacy instruction in the science classroom? This question was supported by five sub-questions as follows:

**RQ1:** What are the prior disciplinary literacy knowledge, training, and development experiences of science educators?

**RQ2:** What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of reading skills?

**RQ3:** What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of writing skills?

**RQ4:** What do participating science educators at the urban middle school do in the implementation of science instruction to support speaking and listening skills?

**RQ5:** What do participating science educators at the urban middle school do in the implementation of science instruction to integrate literacy skills and science and engineering practices?
Teacher actions were viewed through teacher PCK to impact literacy and content instruction in science. A qualitative multiple case study approach was used to guide data collection through interviews, observations, and document reviews (Stake, 1995; Yin, 2014). Each case consisted of a single participant and a nine-week instructional unit. Based on this definition of a case, the study was comprised of three separate cases. Participants in each case referred to with a pseudonym. The first case consisted of a Grade 6 teacher, Kaitlyn, and the implementation of a unit on energy flow in ecosystems. The second case was focused on a Grade 7 teacher, Melanie, and a unit on the structure and function of human body systems. The final case included a Grade 8 teacher, Debra, and an instructional unit on cell division and basic genetic inheritance. Analysis focused on teachers' instructional planning, implementation literacy and science instruction, and assessment practices. Teacher reflection on planning, instruction, and assessment practices was also included.

As presented by Yin (2014), data generated through qualitative case study data was analyzed within each case. Using literature as a source of preliminary ideas, pre-determined codes (Table 1) were used to guide initial coding and categorization of data. After this initial cycle of coding, subsequent iterations of coding were completed to verify categories and develop themes from data to describe how disciplinary literacy is implemented in science instruction (Bogdan & Biklen, 2007; Saldaña, 2016; Stake, 1995; Yin, 2014). The themes generated are reported as related to the categories established in the research sub-questions and include participant prior knowledge and experience with disciplinary literacy, reading, writing, speaking and listening, and science and engineering practices. Prior knowledge and experience aid in understanding the PCK of participants in each case study (Shulman, 1986, 1987). The categories of reading, writing, and speaking and listening align with components of literacy instruction that
may be applied to content area or disciplinary literacy instruction (Fisher & Frey, 2014b; Fisher & Ivey, 2005; NGACBP & CCSSO, 2010). Finally, the presentation of science and engineering practices will provide a context for viewing literacy as applied to science, therefore supporting opportunities for disciplinary literacy instruction (Goldman et al., 2016; Houseal et al., 2016; NGSS Lead States, 2013; Shanahan & Shanahan, 2008, 2015).

After reading and developing themes from individual cases, cross-case analyses were completed to compare and contrast data and strengthen conclusions (Yin, 2014). Categories aligned with the research sub-questions were used to compare and contrast implementation in each area of literacy. Drawing from the within case analyses, cross-case analysis utilized the categories of experience with disciplinary literacy, reading, writing, speaking and listening, and science and engineering practices. These categories make up major components of disciplinary literacy instruction. Therefore, the organization of data based on these categories is logical for understanding commonalities and differences of participant implementations of components leading to the integration of disciplinary literacy instruction.

The presentation of findings is organized by each of the five research sub-questions. Findings for each case are reported prior to analysis of the major components of literacy as identified in literature (Fisher & Ivey, 2005; Moje, 2008, 2015; NGACBP & CCSSO, 2010; Shanahan & Shanahan, 2008, 2015). Findings for each research sub-question are synthesized to understand how individual participants implemented disciplinary literacy instruction in science classrooms of an urban middle school. Individual results for both the research question and sub-questions are then combined through cross-case analysis to inform conclusions about disciplinary literacy in science instruction (Stake, 1995; Yin, 2014).
The study focuses on current teacher practice and does not include training or interventions outside of the participants’ typical responsibilities. To allow for within case and cross-case results, data analyses are reported as three individual case studies (Kaitlyn, Melanie, and Debra). Data collection included interviews with participants, observations of classroom instruction, and document reviews of lesson plans and materials used by teachers in presenting lessons (Figure 1.).

Description of Participants

This study was comprised of three cases representing literacy instruction in science in Grade 6, Grade 7, and Grade 8. A summary of each case is provided in this section. Participants are three teachers in an urban middle school and all are teachers of science. Each participant teaches science at one grade level, ranging from Grades 6-8. Teaching experience varies between participants as does prior training and experience with literacy instruction in science. A summary of participants’ experiences is presented in Table 2. All participants taught science during the 2017-2018 school year at the same public middle school. Participants have been assigned pseudonyms to maintain their anonymity.

**Kaitlyn.** Kaitlyn is a 44-year-old Caucasian female and maintains a state teacher certification in Grades K-6 instruction. She attained a master’s degree in elementary education in 2002. Due to levels of teacher certification determined by the state department of education, an elementary (Grades K-6) is necessary for teaching Grade 6, even in a middle school with separate courses focused on content. Specialized content certifications are typically at the Grades 7-12 level. Therefore, Kaitlyn is considered highly qualified in the area of science due to experience and district documentation of competency in science instruction. Kaitlyn is currently in her 20th year of teaching, which includes seven years of elementary teaching and 13 years in
her current position teaching Grade 6 science. The district science curriculum has been largely unchanged throughout Kaitlyn’s first 12 years of teaching science. However, the state and district have adopted the NGSS, and Kaitlyn is preparing for the implementation of these standards and related pedagogy.

Table 2

*Participant Background and Experience*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Highest Degree</th>
<th>Experience</th>
<th>Assignment</th>
<th>Literacy Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaitlyn</td>
<td>M.S.</td>
<td>20 years overall, 13 years teaching science</td>
<td>Grade 6</td>
<td>District provided and individually sought trainings</td>
</tr>
<tr>
<td>Melanie</td>
<td>M.S.</td>
<td>11 years teaching science</td>
<td>Grade 7</td>
<td>District training; NGSS professional development with embedded literacy; After school teacher-led training (facilitated by researcher prior to research)</td>
</tr>
<tr>
<td>Debra</td>
<td>M.S.</td>
<td>2 years teaching science</td>
<td>Grade 8</td>
<td>District NGSS training; College course on general literacy</td>
</tr>
</tbody>
</table>

Kaitlyn’s classroom was bright and inviting. The room was located on the ground floor and blinds were kept open to allow in natural light. Colorful posters with encouraging quotes or sayings decorated the walls. Cabinet doors served as a word wall with vocabulary words written on the glass panels with window markers and organized alphabetically. On the bulletin board under the upper cabinets, student work was displayed. This work primarily consisted of student created models of their understanding of science concepts being studied. These models appeared in various iterations throughout the observations as students added to and revised their thinking. Kaitlyn arranged student tables into four groups with three tables per group. Each group could
seat up to six students and groups typically consisted of four to six students, depending on class size. School supplies were organized in the center of each group.

   Kaitlyn teaches four periods of Grade 6 science each day and one period of remediation and enrichment. The remediation and enrichment period included flexible groupings of students as determined by Kaitlyn and her colleagues on the academic team. For Kaitlyn, this period is an instructional period focused on student needs in learning science. Activities in the remediation and enrichment period are tied to content being learned in the regular science class periods. In each of the instructional periods, students understood the routines that were established in Kaitlyn’s classroom. Student’s would take out their notebooks and follow directions posted on the interactive (SMART) whiteboard. Kaitlyn explained that initial directions varied depending on the activities planned for each class period and were completed while Kaitlyn took attendance, addressed students returning from absences, and attended to other issues, which was consistent with observations in the classroom. Kaitlyn then presented oral directions that allowed students to hear and understand the progression of the lesson for the day. The verbal overview often contained references to either a unit or lesson level phenomenon that could drive instruction and make connections transparent or relevant to students, such as a reference to the anchoring phenomenon of declining barn owl populations and the causes and effects of this change in relation to energy flow in the ecosystem. Class concluded with a review of ideas figured out in the class period and summarized in student notebooks, as part of a graphic organizer or foldable, through discussion or as an exit ticket.

   Melanie. Melanie teaches Grade 7 science at BMS and is a 32-year-old Caucasian female. She has three separate science teaching certifications that include biology, physics, and Earth and space science for Grades 7-12. Melanie first obtained a biology certification during her
undergraduate work. Additional certifications were attained as Melanie completed two master’s degrees, one each in physics and Earth and space science. Melanie has taught Grade 7 and Grade 8 science for 11 years. The last five years of Melanie’s teaching career have been at BMS. She has served as team leader for her academic team and as the science department chairperson of the school for the past two years.

Melanie’s classroom was located on the second floor and was organized with storage areas for supplies and in progress student work. Student drawn models displaying human body systems and processes within these systems were hanging on the upper cabinet doors. These models were referred to as the “right now” thinking of the class. Station labels and various pieces of student work were displayed on the bulletin board area under the cabinet. Walls contained posters related to science skills and ideas. Melanie used the student tables to create groups made up of two tables to seat four students. Groups were arranged in three rows with two groups per row.

Melanie teaches four periods of Grade 7 science and one period of remediation or enrichment each day. Similar to Kaitlyn as described earlier, the remediation and enrichment period is a flexible grouping of students that is created and can be changed by Melanie and her academic team colleagues. Instruction in the remedial or enrichment period taught by Melanie was focused on science. In each of the four daily science classes, Melanie has established a routine in which students enter the classroom and respond in writing to a prompt or question shown on the interactive (SMART) whiteboard. After taking attendance and answering student questions, Melanie checks each student’s science journal for completion and then facilitates a brief discourse about the prompt. The prompt and ensuing discourse is then used to transition to
planned classroom activities. Learning from the class is verbally summarized by students at the closure of class.

Additional routines in the class are centered on homework activities. Melanie requires two assignments each week. The first assignment requires students to read an article pertaining to the current science topic being studied. After completing the reading, students complete a “one-pager” that includes a five-sentence written summary, a pictorial or visual summary, and a key quote from the article. The second weekly assignment asks students to define either a given list or self-generated list of vocabulary used in the study of science concepts planned for the week. Definitions were to be generated from contexts of reading or class study and not defined using a dictionary or textbook. Both assignments are to be completed independently and outside of class time.

Debra. Debra is a beginning teacher in her second year of teaching. She is a 24-year-old Caucasian female teaching Grade 8 science at BMS. Debra completed her master’s degree in education prior to beginning her first teaching assignment. She has science teaching certifications for Grades 7-12 in biology and general science. As a novice teacher, Debra is completing a required mentorship program with an experienced teacher at the school. This mentorship provides structure for research, modifying instruction, and reflecting on impacts to teacher practice and student achievement. The formalized mentorship is a two-year process, and Debra expects to complete the requirements this school year.

Debra’s classroom was located on the third floor. Walls of the classroom were decorated with posters that included science information, encouragement, reminders of expected behaviors, and a large series of posters for a writing strategy. On the bulletin boards under the upper cabinets were teacher provided exemplars and samples of student work. On the counter near the
Debra has provided reading material, mostly science magazines, for students who may finish particular tasks more quickly than other students. A table in the front of the classroom was used by Debra to organize papers and materials for the class. Student tables were organized into five groups. Three groups were made from two tables with seating for up to four students. Two groups consisted of three tables and seating for up to six students per group. Two groups were in front of the room and the three two-table groups were in the back of the room.

Debra posted a class agenda on the interactive (SMART) whiteboard at the beginning of each class. Students were given the opportunity to prepare for class by reading the agenda as Debra took attendance. The typical routine included Debra reviewing the agenda and asking questions to either review prior learning or transition to activities and learning in the science class. Closure of class included either student or teacher verbal summaries of learning from the class period. Homework was assigned by Debra when appropriate to the lesson and student readiness.

**Presentation of Findings**

Findings from each case and then cross-case analyses will be presented as aligned to the research sub-questions. The organization of findings based on these sub-questions will present components of literacy and science instruction to explain how teachers planned and implemented disciplinary literacy in the science classroom. After the presentation of findings for each research sub-question, general themes that describe the teacher actions for the implementation of disciplinary literacy instruction are presented. These themes generated from the findings of the study that included planning and implementation of literacy, impacts of a professional development experience, simultaneous transitions to disciplinary literacy and NGSS, and unexpected or discrepant data. These themes describe the teacher actions that facilitated the
implementation of disciplinary literacy instruction and therefore address the question of how educators move from the concept of disciplinary literacy to classroom implementation in science instruction.

**Presentation of within-case findings.** The research question and sub-questions are used to guide the presentation of within-case findings for each participant. Each case is divided into five sections corresponding to the research sub-questions of the study. The first section describes the participants’ understanding and knowledge of disciplinary literacy as well as any prior training or professional development in disciplinary literacy instruction. The second through fifth sections will describe instructional approaches, successes, and obstacles to disciplinary literacy in the science content area. The second section will also focus on reading as observed in science instruction. The support of writing skills in science instruction will make up the third section. The fourth section will describe speaking and listening skill in science instruction. Finally, the fifth section will describe the integration of literacy skill with science and engineering practices.

When describing implementation related to reading, writing, speaking and listening, and science and engineering practices, successful implementation will be identified as findings that align with planned or expected outcomes. Obstacles will be identified as occurrences that prevent anticipated results from matching actual outcomes.

**Presentation of within-case findings for Kaitlyn.** Findings for the case study of Kaitlyn are presented in this section. The data were gathered in relation to instruction in a Grade 6 science classroom. These findings include findings gathered through interview, observation, and document review data. The findings are presented in relation to the five research sub-questions.

**RSQ1: Disciplinary literacy training and understanding.** Kaitlyn experienced initial training in literacy instruction during her teacher education program in preparation as an
elementary teacher. In both her undergraduate and graduate coursework, Kaitlyn completed courses dedicated to teaching reading and writing to students in kindergarten through Grade 6. Prior to joining the science department, Kaitlyn taught English Language Arts for five years during which professional development sessions were predominantly focused on literacy. Since joining the science department, Kaitlyn has participated in district provided literacy professional development and in experiences that she has independently sought and attended. District provided professional development has historically been focused on generalized strategies to be applied across curricular areas. This is evidenced in the mandatory Project CRISS (Creating Independence through Student-owned Strategies) presented as training tied to graphic organizers and other general strategies to aid in structuring opportunities for improvement of student achievement in reading and writing. In addition to formalized training or experiences, Kaitlyn also identifies collaboration with colleagues as “greatly influencing and contributing to [her] literacy instruction” as colleagues share different perspectives of strategies and the efficacy of strategies in the science classroom.

Kaitlyn views literacy instruction as essential, even in the teaching of science, stating that she is “constantly teaching literacy” and that science “is just my avenue and content in which to do it [teach literacy].” Kaitlyn approaches the teaching of literacy in science as a balance that accounts for the conceptual understanding of science and vocabulary knowledge necessary for expressing understanding in a variety of forms. When describing disciplinary literacy, Kaitlyn often includes references to or descriptions of general literacy strategies shown in Table 3. In the descriptions of literacy strategies, Kaitlyn grounds each strategy in reading and responding to a traditional text, such as an article or textbook with occasional use of video. While her initial
descriptions included a focus on strategies, observations and later interviews demonstrated a broader view of literacy instruction in science.

Table 3

_Literacy Strategies Observed in Kaitlyn’s Instruction as Summarized by the Researcher_

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Literacy Focus</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text Codes</td>
<td>Reading</td>
<td>Use symbols to identify key pieces of information when reading</td>
</tr>
<tr>
<td>Highlighting or Underlining</td>
<td>Reading</td>
<td>Underline or highlight key ideas when reading</td>
</tr>
<tr>
<td>Active Reading</td>
<td>Reading</td>
<td>Includes a variety of strategies that include previewing a text, reading with a purpose or question in mind, marking the text with notes and questions, making connections, and summarizing</td>
</tr>
<tr>
<td>Quick Sketches</td>
<td>Reading and Writing</td>
<td>Draw and label or describe pieces of a quick sketch to summarize reading</td>
</tr>
<tr>
<td>One Sentence or Two-Dollar Summaries</td>
<td>Reading and Writing</td>
<td>Summarize information from reading in one sentence or within defined parameters</td>
</tr>
<tr>
<td>Diagram with Labels</td>
<td>Reading and Writing</td>
<td>Create a diagram from reading that includes information relevant to purpose or explanation of phenomenon</td>
</tr>
<tr>
<td>Graphs and Charts</td>
<td>Reading and Writing</td>
<td>Create from reading to represent data or information contained in reading</td>
</tr>
<tr>
<td>Partner or Small Group Talk</td>
<td>Reading and Speaking and Listening</td>
<td>Small group or partner discussion about information contained in a reading or a given prompt</td>
</tr>
<tr>
<td>Large Group Discussion</td>
<td>Speaking and Listening</td>
<td>Sharing and building on evidence to construct knowledge and develop a consensus for an entire class or large group</td>
</tr>
</tbody>
</table>

In response to changing science standards and instructional approaches, Kaitlyn used literacy in different ways that reflects an evolving understanding of disciplinary literacy. Reading traditional texts, including textbooks and articles, and engaging in active reading behaviors, such as using text codes and marking the text, were used to provide students with background information in the phenomenon of declining barn owl populations. When planning for subsequent lessons on the barn owl population and energy flow, Kaitlyn identified the use of
diagrams, charts, and graphs as forms of reading that provided opportunities for “students to be able to interpret, whether it’s through graphs or data, to gain new knowledge.” The use of literacy became more authentic to uses within science. As Kaitlyn summarized, “They [the students] have to have some literacy base to their science understanding to communicate it.” Literacy instruction is incorporated by Kaitlyn as a means of “taking the information” from different sources to “create a model, explanation, or conclusion” in ways similar to the uses of scientists.

Kaitlyn did not explicitly define disciplinary literacy as a process different from content area literacy, though she did describe different approaches to teaching and using literacy in science teaching and learning. Kaitlyn explained that the initial instruction in the unit focused on teaching skills for gathering information from nonfiction text. General strategies that included marking the text, creating and using symbols to code the text, and determining the author’s purpose for writing the text were directly taught by Kaitlyn and practiced by her students. Kaitlyn identified this instruction of general strategies as an important component that prepared students for engaging in science practices. As the instructional unit progressed, students were expected to use literacy skills to engage in the science and engineering practice of obtaining information from various sources. The transition of Kaitlyn’s pedagogy from direct, general strategy instruction consistent with content area literacy to application of literacy skills as used by scientists reflects disciplinary literacy. Kaitlyn emphasized the importance of literacy in learning and communicating about science and demonstrated a range of instruction that included content area and disciplinary literacy approaches.

**RQ2: Reading.** Reading in Kaitlyn’s planning and teaching was primarily associated with students getting information or knowledge from the text. Kaitlyn included reading of traditional
texts, such as textbooks and articles, but expanded the definition of reading to include the use and interpretation of charts, graphs, diagrams, and models. In one example, Kaitlyn scaffolded opportunities to understand energy flow through the creation of a three-dimensional foldable that aided the visualization of trophic levels and was used to make interpretations discussed to address impacts of fewer barn owls. Think-alouds were also used by Kaitlyn to scaffold the use of graphs and diagrams as data sources related to the anchoring phenomenon. She pointed out that the use of diagrams is “absolutely reading, because it is a way of getting information you need.” The definition of text to include a variety of sources beyond traditional written text allowed Kaitlyn to plan and implement opportunities and experiences for learning and using literacy strategies and skills that move from content area to disciplinary approaches within the unit and throughout the school year.

Planned and spontaneous read-alouds provided opportunities for Kaitlyn to model reading strategies in general and as pertaining to science. Read-alouds were used for articles and directions to be followed by students. Text codes and underlining or highlighting to mark the text were often paired with read-alouds. The reading would be initiated by Kaitlyn with responsibility released to students with guidance from Kaitlyn for incorporating strategies and identifying key information. The release of responsibility occurred over the first two to three months of school depending on student response to cues and overall readiness.

Early in the school year, Kaitlyn employed an approach consistent with content area literacy which she describes as a “more teacher-directed process.” Kaitlyn states that:

If you would walk into my classroom in September, it [literacy instruction] is so teacher directed, there is no wiggle room. It’s, ‘You will do,’ but through my modeling, I do think-alouds, they [students] understand it [literacy] is a process of thinking to interpret,
understand, and comprehend. Then we slowly go through where I do that gradual release with the kids.

In Kaitlyn’s planning and reflection, she identified think-alouds as a key pedagogical tool for engaging students, saying, “the kids laugh, but they also begin to understand the processes.” Think-alouds were used both in direct instruction of content area strategies and in the release and support of students applying literacy in learning science content and practices.

Think-alouds were used to serve the dual purposes of teaching content area strategies and preparing students to apply literacy in science settings. During a reading, Kaitlyn would make her thinking processes visible to her students. At natural breaks in a shared reading, Kaitlyn would interject her thinking by saying, “If I was a sixth grader, I would think that about a certain idea,” or by asking, “If I was a sixth grader what would I find important? How would I know?” At early points in the year, Kaitlyn would describe specific strategies and processes used to determine important or relevant information in a reading passage. As instruction progressed, Kaitlyn used think-alouds to transfer thinking from strategies to application within science, changing her prompt to, “If I am a scientist studying barn owls, how could I get information? What do I need to know from the reading?” The changes in the think-aloud prompt represents a re-emphasis on science practices and how scientists use literacy.

In addition to think-alouds, Kaitlyn taught active reading strategies that included marking the text or adding codes to the text while reading. Initially, the text codes were provided to students with the expectation that codes be applied in similar ways by all students. For example, in reading about barn owls, students underlined text related to driving questions about barn owls in the ecosystem and coded the information with a “C” for connections, “?” for questions or information not understood, “!” for new learning, and “V” for ideas that could be visualized. As
teaching and learning progressed, students could independently develop codes and apply them to the various forms of text.

Reading instruction also included the use of graphic organizers which varied from teacher created to student generated, fitting with Kaitlyn’s description of the progression from teacher-directed to gradually more student-centered instruction. Drawing from ideas learned through Project CRISS, Kaitlyn first presented organizers with directions linked to a specific reading task. As learning progressed, Kaitlyn allowed students to choose a type of organizer to gather and organize information to support science learning. The use of graphic organizers supported reading for information as well as building of science knowledge by organizing pieces of instruction.

One important distinction that applies to Kaitlyn’s pedagogy is her definition of reading. Whether applying think-alouds, text-codes, graphic organizers, or other strategies, Kaitlyn believed that reading included more than traditional written text. She stated that reading is “crucial” and “is part of having students be able to interpret and comprehend, whether it’s graphs, data, diagrams, or models.” When teaching, Kaitlyn used resources that reflected her views of text and their uses in science. Kaitlyn provided opportunities for analyzing graphs and charts that pertained to driving questions about barn owl populations and leading to the construction and analysis of food chains, food webs, and energy flow diagrams. Kaitlyn utilized the same strategies or instructional techniques tailored to the type of text.

Overall, reading instruction in Kaitlyn’s science classes included a mix of content area and disciplinary literacy. This mix of instruction was initially teacher-directed and focused on generalized strategies and moved toward disciplinary applications in science learning of content and practices in what Kaitlyn described as “very purposeful” planning and implementation.
Strategies commonly used by Kaitlyn were adapted to support student learning from content area literacy instruction to disciplinary literacy application of science practices. While she struggled with her that “NGSS seems to waiver with its literacy support,” Kaitlyn also identified that reading different forms of text as “absolutely crucial with this whole new NGSS.” Kaitlyn’s difficulty in aligning reading instruction with science as presented in new standards did not appear in her planning and delivery of instruction. Lessons within the unit were coherent and designed with the intention of developing student capacity for science work, including content and practices presented in NGSS.

*RQ3: Writing.* As Kaitlyn planned, implemented, and reflected on the use of writing in science, instructional activities focused on ways to express understanding. Written expressions varied in length and form, ranging from single sentence summaries to summative reports or presentations. The differing lengths and duration of writing assignments demonstrated various methods used by scientists. Prior to students applying writing skills as scientists, Kaitlyn structured opportunities for transferring writing skills learned in English Language Arts (ELA) classes. Students would be reminded about ELA learning through general verbal prompts, such as Kaitlyn saying, “Remember what you have been learning in ELA.” In one specific instance, Kaitlyn was helping students develop topic sentences for summaries of articles. Kaitlyn said:

Remember learning about a hook in ELA? In our science writing, we need a topic sentence that’s a bit different from a hook but informs the reader and tells them what you are writing about. How will you begin? What will be your topic sentence?

The transfer of writing skills from ELA to science writing shows the use of generalized, content area literacy skills. However, these general skills were adapted to use in the science discipline, demonstrating a transition of general skills to disciplinary use.
To aid students in constructing summaries, Kaitlyn used varied scaffolds that included pre-writing organizers, “gotta have it” word lists, and what she calls “two-dollar summaries.” Pre-writing organizers provided a template for students to compile information before beginning the process of writing about or summarizing that information. In one example, students used a “tree organizer” to record aspects of a barn owl ecosystem prior to summarizing how the barn owl gets energy and where the energy comes from or how energy flows through the ecosystem. Other scaffolds included a list of key science terms that needed to be included in explanations or summaries of science learning. The list of key terms was referred to by Kaitlyn as the “gotta have it” list. While Kaitlyn focused on science concepts and vocabulary in writing, she also wanted students to understand the importance of concise writing. To scaffold the process of writing to communicate information in a succinct manner, Kaitlyn would assign monetary values to different words, such as 25 cents, 10 cents, or 5 cents. Students then had to include main ideas and summarize concepts using words that did not exceed a total of two dollars. Kaitlyn valued these “two-dollar summaries” as a demonstration that summaries do not need to be long or complex pieces of writing. As students became comfortable with summarizing, Kaitlyn removed scaffolds, but continued to utilize summaries as the most common form of daily writing in science classes.

Summaries represented the most common form of day-to-day writing in Kaitlyn’s science class but were not the only form or use of writing. Longer writing assignments that included multiple drafts and revisions were associated with student-generated scientific models and summative tasks. Students created models to demonstrate energy flows in an ecosystem and the relationship to the phenomenon of declining barn owl populations. These models were revisited and revised throughout the instructional unit and therefore allowed students to improve writing
through proofreading, checking grammar, and elaborating science content. Writing in models included labeling and brief explanations on the model as well as explanations that accompanied the model. The use of summaries to explain representations was consistent with the use of explanations written by scientists and supported student-developed diagrams, illustrations, or other visual representations. Modeling of science ideas provided opportunities for students to elaborate ideas over time, beyond a single class period or portion of a class period. Kaitlyn described modeling as both a scientific practice and scaffold for students to “include their understanding of the words in the diagram or to explain them separately.”

Kaitlyn structured varied opportunities for students to document their construction of knowledge and developing understanding of science. As described by Kaitlyn, she was shifting her pedagogy toward “more student-centered demonstration of the concepts with open-ended type assessments.” This emphasis was visible in Kaitlyn’s instruction as she modeled and later allowed students to choose different types of “outputs” within their science notebooks, each of which incorporated writing in some form. Short-term and long-term writing activities included brief summaries, sketches or diagrams with labels and captions, models with explanations, and summative reports and presentations. Kaitlyn began the unit by reminding students of writing skills learned in ELA and then gradually moved instruction throughout the unit toward opportunities to apply writing as scientists, representing a changing emphasis from content area literacy to disciplinary literacy experiences.

**RQ4: Speaking and listening.** Speaking and listening skill development was identified by Kaitlyn as an area of growth for students and for Kaitlyn. Kaitlyn stated that she is working on “moving away from, ‘You’ve got it!’ or ‘That’s right!’ to, ‘What makes you think that? What evidence can you provide to support that answer?’” She continued:
It’s hard changing my response to my students to build confident science learners who can be willing to take a risk, answer a question, and not get the quote, unquote, teacher answer that they have been looking for and I have been giving for all these years. It’s huge to change that classroom culture that I’ve been engrained in for 20 years and I continually work on that.

Much like she scaffolded opportunities for developing reading and writing skills, Kaitlyn used different methods to build student confidence and facilitate discourse focused on science ideas and supporting evidence.

Prior to opportunities for developing speaking and listening skills, Kailyn created an environment that facilitated discourse, which she described as a “comfortable zone of expectations that we are all here as learners, we’re all here to make mistakes, to grow.” Kaitlyn emphasized that she used personal stories and connects to convey how an eye roll, sigh, or comment could hurt the feelings of Kaitlyn and other students. Once the environment is established early in the school year, Kaitlyn viewed use of discourse as a tool that engaged students. This engagement was evident as students did not hesitate in sharing their models and building on each other’s ideas in both small and large group settings.

The use of discourse was a change in Kaitlyn’s pedagogical approach to science instruction. During the observed lessons, Kaitlyn did not use traditional call and response questioning techniques, but rather she structured opportunities for students to talk, defend and support their ideas, and then reach consensus as a small group or whole class. Kaitlyn engaged students in think-pair-share activities that allowed students to practice speaking and listening before engaging with the whole class. As students became accustomed to sharing, Kaitlyn used a think and speak approach that gave students opportunities highlight, underline, or write a short
list of ideas that they could use as evidence when sharing. Monitoring student engagement and comfort allowed Kaitlyn to plan small group activities or large group discussions that could be predominantly student led with minimal guidance from Kaitlyn.

Students engaged in speaking and listening to aid each other in gathering and analyzing data, sharing ideas, and constructing knowledge through the use of evidence and integration of feedback. Kaitlyn assisted by facilitating discourse using prompts such as, “Can anyone build on what was just shared?” or “Does anyone have any other evidence that supports or disagrees with that idea?” The use of talking involved students in the learning process. Even when not directly facilitated by Kaitlyn, students engaged in talking with each other about science to form ideas. When dissecting owl pellets, students encouraged each other and then assisted in trying to match bones taken from the owl pellets with diagrams and descriptions. Students would turn to another student and ask for their thoughts to clarify confusion or confirm thinking and ideas. Kaitlyn welcomed these interactions during the investigation and complemented students that were working together to understand the data collected.

Kaitlyn described opportunities for speaking and listening as an area of growth for both her and her students. Kaitlyn responded to the challenge of meaningful, student-centered discourse by creating an environment that was comfortable for students to express ideas without being judged based on an expected answer. The techniques used by Kaitlyn made the actions of students personal and therefore relevant to students. Kaitlyn was then able to structure opportunities that did not require her to provide affirmation of student thinking but allowed students to build on ideas to clarify understanding or offer a differing perspective. As the school year and the unit on barn owls progressed, students engaged in discourse with fewer scaffolds from Kaitlyn as they constructed knowledge about science concepts.
RQ5: Science and engineering practices. The observed unit implemented by Kaitlyn lasted nine weeks and represented her first teaching of a unit aligned with NGSS pedagogical expectations, particularly science and engineering practices (NGSS Lead States, 2013). Kaitlyn credited fellow teachers in supporting both her understanding and implementation of pedagogy that supports teaching science and engineering practices, stating, “Collaborating with my colleagues greatly influences and contributes to my instruction.” She identified common planning time as essential to learning about how to integrate many components of science instruction, such as content, science practices, and literacy skills. By sharing and planning as part of a grade-level, subject-specific group, Kaitlyn could draw on the expertise of another teacher who had received more extensive NGSS training, thus aiding in the use of science and engineering practices.

Understanding the use of science and engineering practices in conjunction with disciplinary literacy was initially not well received by Kaitlyn. When asked in an initial interview about structuring teaching to develop and support both literacy and science instruction, she responded that she thought the question was “a loaded question.” When elaborating on her response, Kaitlyn shared that she felt “NGSS waivers with its literacy support.” Kaitlyn felt that conceptual knowledge was emphasized in NGSS at the expense of content vocabulary and literacy. She re-emphasized her position by stating, “Students need both conceptual understanding along with the vocabulary knowledge and math skills to demonstrate their acquisition of the content.”

Once Kaitlyn began implementing instruction for the unit, she said she focused on engaging students with content and practices. While Kaitlyn felt the process of planning and teaching students in ways consistent with NGSS was “very overwhelming,” she kept returning to
content, stating, “I look at the DCIs [disciplinary core ideas] and try to figure out the best way for my students to experience the information.” Kaitlyn’s emphasis on “student experiences” allowed for authentic uses of science and engineering practices and disciplinary literacy skills that did not feel contrived or forced into classroom instruction. Students engaged with science concepts while using a variety of science and literacy skills.

As students prepared to explore ideas, Kaitlyn structured scaffolds that included the use of reading traditional texts as background and obtaining information from charts and graphs and writing through documenting procedures and data through summaries, charts, and graphs. Transferring general literacy strategies to science applications supported student questioning, investigations, analysis of data, and argumentation or communication based on evidence. Kaitlyn created opportunities for disciplinary literacy instruction embedded with inquiry and knowledge construction. The integration of skills was evident when students questioned food sources of barn owls. In response to questions, Kaitlyn presented students with the opportunity to dissect owl pellets. Students read about owl pellets to understand what they are and how the pellets could provide relevant information. Students dissected the pellets, gathering bones that were identified by size and shape using a guide with diagrams and captions provided by Kaitlyn. Bones were then identified using the guide, quantities of each were recorded and explanations of energy flow were constructed from the data. Knowledge about food sources and energy flow constructed from the investigation were presented as students identified bones by reading the guide and then recorded the quantities, graphed these quantities and provided a brief explanation of energy flow on a graphic organizer and brief written conclusion. Students were able to use literacy skills in the context of the science discipline to produce, communicate, and support or defend ideas similar to how scientists generate knowledge.
Kaitlyn had inconsistently used an owl pellet dissection activity throughout her time teaching Grade 6 science. In past years, she questioned the benefits of the investigation, which was more teacher-directed in nature. When planning for use of the owl pellet activity in its present form, Kaitlyn noted the open-ended approach that allowed students to construct an understanding of food sources and energy flow rather than verifying ideas previously presented through lecture or notes. Kaitlyn viewed this process as essential in helping students see the relevance of science and develop a level of comfort in learning about and engaging in science.

Students entering BMS in Grade 6 are from five different elementary schools. Even though all of the elementary schools are within the district, Kaitlyn shared that students have a wide range of experiences related to science. Due to these differences, Kaitlyn identified building comfort with and developing a common understanding of practices in science. One method for bridging gaps between prior knowledge and current expectations was planned opportunities for students to use familiar skills, such as content area literacy strategies, in the context of science. Kaitlyn initially provided graphic organizers and connections to argumentative writing with which students were familiar to build capacity for science practices, such as the use of evidence in defending conclusions.

As students became comfortable and confident in the use of science and engineering practices, Kaitlyn also embraced the integration of literacy within the practices. In a final interview reflecting on the unit, Kaitlyn spoke enthusiastically about opportunities for the use of literacy due to pedagogical changes consistent with NGSS. She viewed diagramming, modeling, and investigating as a link to building science and literacy skills “especially with the whole new NGSS.” She reiterated that she is “constantly teaching literacy” through science. Literacy observed in Kaitlyn’s classroom aligned with applications of literacy skills relevant to science as
opposed to general content literacy. These applications were consistent with uses in the science discipline, such as reading and interpreting data to gain and evaluate information and communicating and supporting ideas with evidence. As Kaitlyn practiced implementing instruction aligned with NGSS, her pedagogy included a renewed emphasis on disciplinary literacy as demonstrated through student-centered tasks rooted in the use of literacy in science.

**Conclusion.** The emphasis of literacy instruction in Kaitlyn’s classroom was initially represented in content area or general strategies, such as marking informational text to decode and gather information. As Kaitlyn worked to develop pedagogy and content knowledge to meet expectations of NGSS implementation, the instruction on and use of literacy was more prevalent in the applications of science and engineering practices. Kaitlyn provided opportunities for students to obtain and evaluate information on a daily basis through reading and interpreting a variety of traditional written texts, charts, graphs, and data sets. After reading and gathering information, opportunities were provided by Kaitlyn for communicating understanding through written responses, modeling, and verbal sharing of ideas. Kaitlyn allowed students to investigate questions through research and laboratory activities that used disciplinary literacy to construct science knowledge in the classroom.

**Presentation of within-case findings for Melanie.** Findings for the case study of Melanie are presented in this section. The data were gathered in relation to instruction in a Grade 7 science classroom. These findings include findings gathered through interview, observation, and document review data. The findings are presented in relation to the five research sub-questions.

**RQ1: Disciplinary literacy training and understanding.** Literacy training was absent from Melanie’s preservice education and the early portion of her teaching career. Melanie stated that she had “little to no training in terms of literacy training in the science classroom.” As Melanie
has prepared for transition to NGSS-aligned instruction, she has engaged in ongoing professional
development provided by a local university. Her three-year engagement in the professional
development project was described by Melanie as “the largest influence in my approaches to
literacy instruction as well as the new science standards [NGSS].” The impacts of these
experiences are visible in approaches to instruction within the science classroom and on
homework assignments that build literacy skills and science practices.

Melanie initially defined literacy as “a means to be able to teach science. The literacy
pieces that are a part of science serve to be a delivery method for instruction.” Melanie viewed
literacy in science as an important tool for communicating within the science discipline. Drawing
on lessons learned in the professional development project, Melanie identified the need for
literacy instruction to be meaningful and integrated in ways that were relevant to science. As
students read, write, speak, listen, and employ science practices, Melanie believed that students
could “expand science knowledge and literacy skills.” To accomplish literacy instruction in
science, Melanie describes a balance that includes structuring “multiple opportunities, a variety
of methods, as well as varied levels in terms of ability” that enable integration of literacy, science
and engineering practices, and science content knowledge. Melanie describes learning being
expressed through student abilities to gather information, construct ideas, and communicate
understanding.

In describing implementation of literacy instruction in science, Melanie focused on
“embedding literacy strategies into content.” She stated that her efforts were informed by the
development at the local university and aligned with her teaching style. Discovery and
construction of knowledge is key to Melanie’s teaching. When describing her approach, Melanie
focused on discovery and literacy as a tool, stating:
My approach to teaching science and literacy is, overall, that of discovery. Students need to be interested in what they are learning and excited to find out answers. If students can approach literacy with the same mind set, that they are excited to be finding out answers, then literacy has just become a tool to aid in learning, rather than something that itself [literacy skills] needs to be taught.

The approach utilized by Melanie in her classroom using “literacy as a tool” applied literacy skills in ways that parallel uses by experts in the science discipline.

Two phases of literacy instruction were evident in Melanie’s implementation. Melanie delineated work completed at home and in the classroom, which demonstrated differences in content area and disciplinary literacy as well as connections between these approaches. Melanie provided two weekly homework assignments for students that incorporated literacy skill use and development. One assignment required students to define vocabulary words based on assigned readings and appropriately use the terms in sentences. This assignment develops a general literacy strategy of developing vocabulary and, in some cases, pre-teaching science vocabulary terms. The second weekly assignment centered on a current article relevant to the topic being studied in class. Melanie provided a graphic organizer for an assignment termed a “one-pager” and included a written summary of the article, a picture or series of pictures to represent key ideas from the article, and an important quote from the article with a reason for its importance (Figure 3.). General strategies for summarizing information are practiced when completing the one-pager assignment. Both weekly assignments include content area literacy strategies, such as vocabulary development, summarizing, and determining key ideas in a text.
While homework assignments provided by Melanie utilized general strategies for reading and writing, these activities were not devoid of content. Melanie purposefully selected articles that were relevant to topics being studied, included current events, and were at appropriate levels for students. Articles were used to make science context real and meaningful to students. Melanie capitalized on student interest and questions generated by homework assignments to drive classroom instruction and use of skills in classroom activities. Opportunities to develop content area literacy skills or generalized strategies were fostered through graphic organizers and mini-lessons that included modeling and direct instruction. Generalized skills and information gathered through reading informational text aided in disciplinary uses of literacy as contained in
the science and engineering practices of constructing an argument and communicating an understanding of science ideas and concepts.

When in the classroom, students applied skills to model processes in human body systems, discuss ideas about relationships within and between systems, and investigate components of systems. The opportunities for applying literacy in science where planned by Melanie with a primary focus on what she called “science knowledge and content building.” Melanie stated that “students need to be literate in order to learn content.” To accomplish construction of knowledge and development of literacy, Melanie concluded that “strategies used to build content knowledge are often building literacy.” The connections of content knowledge construction and disciplinary literacy were observed in formative assessments such as models, written responses, discourse, and oral presentations of ideas. In formative assessment tasks, Melanie created performance tasks that paralleled activities used by scientists. In Melanie’s planning, she created situations where “being literate is necessary in order to complete the science task.” Tasks were rooted in the science concepts and required the use of science practices and literacy skills. This was evident in the research required to obtain information about human body systems used to develop models of the function and importance of systems prior to presenting written and oral explanations of each system and, ultimately, the relationships between the systems. Throughout instruction and assessment tasks, Melanie planned for literacy to be embedded with science content.

As Melanie has gained experience with literacy use in the science discipline, she felt that literacy is second nature in planning. She feels that integration of literacy and science skills “is done often and without as much strategic planning as one might think,” thus reflecting Melanie’s development in the pedagogy and content of literacy instruction in science. Melanie further
explained that, “As I have grown as a teacher, I have added to my array of literacy building tools that now have just become the means to teaching my content.” The instruction of literacy skills as separate or distinct and general strategies was not apparent in Melanie’s instruction and were not considered as such in her lesson planning. Literacy was visible, both in planning and practice, as tools for accessing content information, constructing concepts, and communicating understanding.

**RQ2: Reading.** Melanie considered reading to be a process that allows students to “gather information” about science content. She supported reading through providing “current articles for students to read related to the current topic.” Sources of articles included science-themed magazines and websites. Beyond reading traditional texts such as articles, Melanie described opportunities for literacy development “specific to science, such as being able to analyze scientific data and reports.” Melanie viewed interpretation of data, graphs, and diagrams as forms of reading. This view is consistent with Melanie’s use of reading as a means of gaining information to build understanding and construct knowledge of science concepts.

Melanie encourages reading in her science classroom in a variety of ways and through the application of various strategies. She identified her instruction as being “structured to provide multiple opportunities to understand text.” When teaching about human body systems, Melanie planned for and utilized diverse forms of text that allowed students to access information and construct knowledge about individual systems and how systems interact within the body. One use of reading was evident as individual systems were explored through articles about the functions of a system. Articles were assigned to be read and summarized as homework or as part of a jig-saw activity in class. General strategies were reviewed prior to student reading and included use of a guiding question to focus attention on main ideas and supporting details and
methods for marking the text to code important information. Reading traditional text was motivated by Melanie due to the relevance of topics studied and the purpose for students to become experts prepared to communicate information.

Melanie also approached reading through the use of diagrams. In one example, when exploring the digestive system, Melanie provided a diagram that did not contain labels or captions. Similar to marking or coding the text of an article, students coded processes in digestion, such as mechanical digestion, chemical digestion, transport, and absorption, by color coding the diagram. This activity was structured by Melanie to draw on prior experiences and knowledge and apply understanding to the interpretation of the diagram. In other uses of diagrams, Melanie structured gallery walks for students to read diagrams created by peers. Students interpreted diagrams and read labels and options to drive questioning and feedback that could lead to additional activities for gathering information. In addition to reading, the use of student generated diagrams also included the use of writing and speaking and listening skills, which will be presented in later sections.

To further focus literacy in science, Melanie also used charts, graphs, and data tables in her instruction. As observed in the use of diagrams, Melanie used both charts, graphs, and data tables given to students and resources generated by students. Melanie expressed a desire for students to have a “discovery mindset” in both science and literacy. The use of charts, graphs, and data tables provided sources for Melanie to encourage discovery through reading and interpreting data. She allowed students to identify patterns, trends, and connections in the information presented and beyond the data for application to the broader topic of study. The uses of tables, charts, and graphs were consistent with Melanie’s definition of reading because the process included interpretation and gathering of information.
The use of multi-step procedures for investigations provided opportunities to combine traditional reading skills with the use of diagrams, tables, charts, and graphs. Melanie planned lessons that allowed students to develop questions and then investigate to build knowledge and determine answers. The use of investigations varied as Melanie would either provide procedures or require students to develop their own procedures. In some cases, students progressed from a given procedure to design investigations that were specific to their own questions. For example, when studying the skeletal system, Melanie planned a lesson to investigate joints using an activity to build a “robotic finger.” This activity included a multi-step procedure for assembling the finger from a paper template, but after construction, allowed students to determine the next steps to answering questions about joints in the finger and comparisons to movements of various types of joints observed in their bodies. Data were recorded in data tables that were later interpreted by students. Melanie planned opportunities such as the robotic finger to incorporate reading without investigations being entirely prescribed by the teacher. The incorporation of reading through the use of multi-step procedures is consistent with literacy uses in the science discipline.

Reading was identified by Melanie as a means of gathering information and was applied in the classroom using different strategies and a wide variety of texts. Content area reading strategies are reviewed and used in research and reading for information about science ideas and concepts. Reading in Melanie’s planning and instruction also included opportunities to apply literacy to science practices and learning. The use of literacy to read and interpret charts, graphs, and diagrams represents a broader consideration of text that Melanie utilizes to create opportunities for gathering information. Experiences using reading to construct science
knowledge reflected the activities of scientists and were used by Melanie in planning and implementing relevant learning opportunities for students.

**RQ3: Writing.** Writing in Melanie’s science classes took different forms but revolved around expressing ideas and communicating knowledge. This communication of knowledge was not reserved for summative assessments but included ongoing evidence of current perceptions or conceptions of the science topics being studied and allowed both Melanie and her students to track revisions in thinking. Returning to Melanie’s view regarding “multiple opportunities to understand a text,” various methods to express understanding were apparent in Melanie’s planning and instruction. Writing tasks included brief summaries of learning from a lesson, writing that demonstrated learning over a series of lessons or extended time frame, and constructed responses used as summative assessments.

The nature of tasks planned by Melanie required students to draw from evidence acquired through reading, investigating, and discourse. When gathering information from reading and research, Melanie used graphic organizers to support student writing. The general organizers could be used with a variety of articles beyond science class, but through Melanie’s choice of article, the focus of summarizing was on science content. One organizer referred to as a “one-pager” was part of a weekly reading and writing assignment. The use of the organizer provided the space and structure for a traditional summary of information, but also connected writing to a visual or graphic representation of ideas. Melanie considered the pictorial portion of the one-pager as a diagram to support the building of knowledge through different learning styles, which also supported development of vocabulary.

As Melanie worked to align instruction more consistently with the expectations of NGSS instruction, approaches to vocabulary instruction changed. Rather than direct instruction to pre-
teach vocabulary, Melanie incorporated assignments for defining terms not through looking up words, but by “discovering what they [vocabulary terms] mean from their [students’] reading.” After engaging in independent “work in the skills needed to decode words,” Melanie planned for students to communicate their understanding through definitions written in the students’ own words and used appropriately in student-generated sentences. Melanie structured vocabulary homework assignments to provide opportunities for reading and decoding, but also expressing and communicating understanding through writing. While classroom instruction on determining and communicating meaning and understanding was not prominent, Melanie provided students with opportunities to develop writing skills pertaining to vocabulary through practice and feedback provided by Melanie.

Whether specific to content vocabulary or writing more generally in the science discipline, Melanie did not want to “just tell the students the answer.” She wanted to instead “foster a learning environment that allows students to participate in experiences and discover ways of communicating in science.” Ongoing opportunities for discovering writing in Melanie’s classroom included the use of modeling that included visual and written presentation of ideas and chances for giving and receiving feedback leading to revisions in the writing. Peer and teacher feedback, both written and oral, guided development of necessary components in communicating through writing. When teaching human body systems, Melanie used modeling in discussions of different systems. Multiple iterations of modeling within the study of each system and uses of modeling in the study of six different systems allowed Melanie to support student growth in writing through modeling by circulating in the classroom and asking questions or giving feedback to guide student development. With each use of modeling, Melanie noted student
improvements in writing, both as components on the model and explanations of representations in the model, as the uses of models progressed throughout the unit.

Melanie planned for check-ins and opportunities to push and probe students to not only deepen their science understanding, but to express this knowledge through writing. Melanie planned scaffolded writing from fill in the blank assignments that modeled science writing with opportunities to insert evidence from reading or investigations. Modeling provided additional chances for students to refine writing. Finally, open-ended questions were used as more formal stimuli for student writing about science. Much like presenting multiple opportunities to interpret text, Melanie structured experiences for different forms of writing consistent with uses in the science discipline.

*RQ4: Speaking and listening.* Melanie’s planning for and implementation of opportunities for speaking and listening were centered on discovering and constructing science content knowledge. Table groups and whole class contexts were used to facilitate discourse about science ideas at various stages of development and levels of science understanding. These opportunities for discourse in Melanie’s classroom typically stemmed from structured reading of an article, such as jig-saw activities, and from development and sharing of scientific models. For example, Melanie tasked students with learning about types of joints. She then structured a jig-saw where students left their table groups to research and become “experts” about a certain joint type before returning to share the information with their original table group. The table groups then worked together to incorporate information about joints into their models of the skeletal system. Groups used speaking and listening skills in sharing information to construct knowledge about body systems.
Speaking and listening skills were observed being used in the development, use, and revisions of models. Melanie provided opportunities for students to collaborate as they pieced together information in the construction of knowledge. Each student at the table group had a role or area of expertise that added value to the group and, therefore, made each student essential to the success of the group. Each student needed to speak to share and listen to further understand and create an appropriate explanation. Throughout sharing to develop ideas and models, Melanie would circulate between groups and move from passively listening to students to actively questioning and prompting students to elicit further explanation or reasoning. Melanie would probe by asking questions such as, “Can you tell the group more about that?” or “What evidence do you have for the group?” The use of questioning in small groups fostered discussion and encouraged the use of evidence or data to support the group development of models.

Revision of models also utilized speaking and listening skills. While initial feedback from other groups was written, the groups receiving the feedback engaged in discussion to prioritize and address feedback. Melanie scaffolded this process by guiding conversations through several phases. To begin the discussion, Melanie asked the groups to decide which feedback was useful and which was not useful. Each member of the group was to share and give reasons to support the useful or not useful classification. After identifying and reaching consensus within the group, Melanie asked students to prioritize feedback. Melanie did not designate how groups should prioritize, thereby allowing groups to determine their own approach. As Melanie visited each group, she noted that some groups arranged based on what they perceived as the biggest weakness in their model or the most important question that “needed to be fixed” while other groups ranked feedback based on “what was easiest to change to what will take more time” in the revision of the model. The final phase of revising the model
involved student discourse in small groups to talk about and agree on what changes to make in visual and written components of the model. Melanie visited each group as they progressed through the phases of model revision, both structuring the process and offering guidance through questioning to allow student practice of speaking and listening skills.

The presentation of ideas offered a final opportunity to practice speaking and listening skills pertaining to scientific modeling. Groups presented to the whole class, using a poster of the model to support their explanations of the modeled phenomenon related to human body systems. Melanie established norms to guide both students presenting and those listening to the presentation. Discrete reminders of these norms were given by Melanie when necessary. Melanie would scaffold and build confidence of students though prompts such as, “Can you read what you have written in the corner of your model?” Prompts such as these aided explanations by allowing a starting point from which students could gain confidence and elaborate. In addition to practicing speaking skills, students were also listening to gain information, to formulate questions, and to respond to answer questions or clarify explanations. Presentation of models communicated current levels of science understanding and could be used as formative assessment. When presented as a summation of learning, models could also be used as a group summative assessment. Both approaches relied on the use of speaking and listening skills.

Speaking and listening skills were most prevalent in association with modeling, both in small table groups and as a whole class. The use of speaking and listening skills were also applied through instruction using lecture and question and response activities. During modeling or with the use of articles, Melanie presented brief lectures to clarify or provide information that then could be discussed by students and incorporated in their models. Other activities were teacher directed or developed questions that required student responses. Students practiced both
listening and then speaking for the purpose of checking student understanding or building a common knowledge base for further class discussion or investigation. The use of lecture and question and answer strategies were planned and implemented by Melanie as appropriate or necessary to engage students but did not represent a large portion of instruction and could be viewed as mini-lessons that were necessary in furthering learning.

One obstacle to group development of models was building consensus and keeping all group members engaged in the process. During one class, students were prepared to continue constructing a model about the structure and function of the circulatory system to answer, “How does this system keep us alive?” Students had previously created models of the digestive system and appeared eager to complete the circulatory system model. Melanie did not want to impose teacher assigned roles, but she wanted to be sure students were being thoughtful about their model and not just going through the same processes as in previous modeling activities. She accomplished this by not allowing students to begin immediately writing. Before students could pick up markers or pencils, Melanie asked students to have a discussion to plan their approach. For two minutes, students talked in their table groups about what should be included, what needed done, and the responsibilities of each group member. While students engaged in planning, Melanie circulated around the room listening to ideas and offering guidance for groups that may have been off task. After two minutes, students had clarified goals and roles within the group to reach these goals. The time designated for speaking and listening without writing seemed to be beneficial as students were focused on each other and the ideas being shared instead of on the process of writing or drawing on the model.

Speaking and listening skills played an important role in aiding student construction of knowledge. Melanie attributed the use of speaking and listening skills in building student
understanding to changes in instruction to meet expectations of NGSS. Melanie stated that speaking and listening need “to be practiced often” through an “environment where all questions have merit.” The approach has value to Melanie as speaking and listening created student-centered opportunities that promoted engagement and fostered interest in the science topic and in sharing ideas.

**RQ5: Science and engineering practices.** The curricular emphasis of science and engineering practices embedded with content coupled with professional development at a local university established a foundation for Melanie to use literacy in ways authentic to or consistent with uses in the science discipline beyond the classroom. Melanie had the goal of keeping students engaged, which included discovery. As Melanie described her instruction she stated that her approach is to design experiences that allow students to “engage in discovery” and be “interested in what they are learning” as a means for motivating learning exhibited as “a search for answers.” Melanie viewed science and engineering practices as supportive of her goals for centering instruction on students and providing opportunities for discovery that involved both science and literacy. For this reason, Melanie identified that literacy was becoming part of her science instruction, stating, “More than ever before, I find myself embedding literacy strategies into my content teaching with NGSS.”

Melanie saw parallels in the instruction of disciplinary literacy and science and engineering practices. In Melanie’s view, both literacy and science and engineering practices are tools for gathering and communicating science information. Text includes written text, but can also take the forms of diagrams, charges, graphs, or data that provide information. When planning, Melanie was aware of opportunities for the integration of disciplinary literacy in science to gather and share ideas. She was deliberate in creating ways for students to “discover”
uses of literacy consistent with use by scientists. Melanie approached both planning and implementation in ways that made disciplinary literacy a natural component of science instruction rather than a contrived add-on or separate strategy instruction. Melanie was able to draw on learning from professional development experiences to utilize science and engineering practices as scaffolds for disciplinary literacy and disciplinary literacy skills as supports for science and engineering practices.

Melanie viewed literacy as an integral component of developing science and engineering practices. She planned for students to have “multiple opportunities” for discovering and constructing knowledge through “a variety of methods” that included science and engineering practices. As presented in previous sections, Melanie structured learning opportunities for students to develop and use models to construct and explain understanding of phenomena that demonstrate science concepts. Each human body system studied included the use of modeling which ultimately allowed students to make connections between systems in the human body. Modeling was used by Melanie as a means for students to construct explanations, evaluate and communicate information, and argue from evidence. These practices included writing to compile information and to explain understanding as it progressed through revisions of the models.

Melanie also required students to share and defend choices made in constructing their models and explanations, consistent with the practice of arguing from evidence. While students were developing models, Melanie would visit each group to listen in and clarify thinking or models through the use of probing questions and reminders or references to information students had read or recorded. As one group modeled the muscular system, Melanie refocused the student work by asking, “How do muscles keep you alive?” After the students said that muscles help humans breathe, Melanie pushed student thinking by responding, “You are right. Your muscles
help you breathe, but how?” In a separate modeling activity, students responded with evidence when Melanie asked, “How does the [circulatory] system keep you alive?” However, the evidence presented verbally was not incorporated in the model, so Melanie encouraged students to “decide how you will show that in your model.” Melanie prompted students to remember “the little things” that aid in explaining “how things are happening.” As Melanie engaged students in conversations and questions about their models, she directly or indirectly elicited evidence to support student explanations.

Gathering information was strongly tied to disciplinary literacy in Melanie’s classroom. Melanie’s assignment of articles to be read and summarized represented traditional reading as a source of information, but opportunities for gathering science content information also included analysis of graphs and data and planning and carrying out investigations. Various investigations were incorporated to support learning about human body systems, such as activities to monitor heart rate, muscles and movement, and skeletal joints. When investigating joints, students researched skeletal joints before following a procedure to construct a “robotic finger” out of provided supplies. While the set-up or construction of the finger was prescribed, students were able to develop questions to answer using their robotic finger.

Melanie stated her belief that “activities, whether reading or investigating, need to be interesting and engaging for students.” The use of science and engineering practices and disciplinary literacy aided Melanie in planning and implementing student-centered instruction while allowing her to maintain a degree of flexibility in her planning. Without ability to adjust plans within and between lessons, Melanie would not have been able to provide meaningful student-centered instruction. Melanie extended time for students to work on models or to have class discussions based on student engagement and progress toward expected outcomes. As
students were given additional time for modeling and other activities, Melanie identified pacing as a challenge to fully implementing instruction aligned with NGSS. The incorporation of disciplinary literacy provided a tool for engaging students but did not seem to impact pacing of lessons.

Melanie used disciplinary literacy and science and engineering practices as tools for discovering science content. Reading, writing, and speaking and listening were used in modeling, investigating, gathering, and communicating information. As students gained information, they were able to put pieces of information together to build and revise understanding of science ideas and concepts. While Melanie needed to be flexible in her planning, she supported instructional approaches that were driven by student interactions with phenomena and centered on student questions and needs for learning science.

Conclusion. Melanie emphasized literacy in different ways through the use of both homework assignments and in class instruction. Melanie viewed literacy as a tool for gaining information and therefore supportive of science learning. Learning in Melanie’s class was structured around discovery through the use of disciplinary literacy and science and engineering practices. Students remained engaged as they gathered information from a variety of sources and then pieced together ideas to construct knowledge and explanations or presentations of this acquired knowledge. Melanie used practiced reading traditional text as homework and in class jig-saws as a means of building background knowledge that allowed for students to engage in deeper investigations, research, modeling, and discourse. Melanie identified professional development as a key factor in preparing her and supporting efforts to align instruction with NGSS. She also viewed changes in her instruction resulting from the development experiences as supportive of disciplinary literacy and NGSS-aligned instruction.
Presentation of within-case findings for Debra. Findings for the case study of Debra are presented in this section. The data were gathered in relation to instruction in a Grade 8 science classroom. These findings include findings gathered through interview, observation, and document review data. The findings are presented in relation to the five research sub-questions.

RQ1: Disciplinary literacy training and understanding. Debra’s literacy training was limited to a single graduate school course on general literacy strategies, primarily focused on reading. Debra was aware of her lack of training and its impact on her instruction. She said her “approach to teaching science and literacy is pretty minimal considering I [Debra] don’t have much experience teaching literacy.” As a novice teacher in her second year with little training in literacy instruction in science, Debra relied on strategies she had experienced as a student. Drawing from strategies that aided her personal vocabulary, reading, and science learning, Debra created a learning environment in which she led students in developing similar approaches to understanding vocabulary, reading directions, and writing conclusions. Debra incorporated strategies for reading and writing during inquiry as she planned, as related when she said she “plans how my students are going to explore the concept, how I’m going to explain the content, and how I’m going to assess that they understand it [science content].”

In addition to having limited training in literacy, Debra is in the initial stages of learning about NGSS and the implementation for meeting upcoming curricular expectations. The district provided a three-day training to familiarize teachers with NGSS as well as a two-day NGSS curriculum writing workshop. Debra identified strategies of writing “questions and observations when viewing phenomena and using science talk moves when having discussions” as being most impactful on her instruction. Science talk moves include sentence or question starters that aid teachers in facilitating classroom discourse as described by Michaels and O'Connor (2015). She
expressed that “these strategies learned at NGSS workshops are a useful way to incorporate speaking, listening, and writing skills into every lesson.” While these development opportunities provided a basic understanding, Debra said she is “continuing to learn more about implementing NGSS.” As a novice teacher with a basic understanding of NGSS and limited training in literacy instruction in science, Debra does not have a broad background of experiences or pedagogies from which to draw as she attempts to meet curricular changes and needs of her students.

Even though she lacked a considerable amount of literacy training and was still learning NGSS, Debra viewed literacy as important to learning science. She stated that disciplinary literacy “means you’re teaching students to be critical thinkers and develop reasoning skills in reading and inquiry.” Debra used reading and writing in science as a means for guiding and assessing inquiry as students would read directions and then write conclusions at the end of inquiry experiences. Teacher lead questioning and discussions would be used to aid students in deeper thinking about content being explored. As Debra continued her learning about NGSS, she implemented modeling as a means for integrating additional opportunities for students to practice and develop skills for questioning and critical thinking.

Debra stated that literacy skills could be incorporated “into every lesson,” specifically identifying “speaking, listening, and writing skills.” While Debra identifies the potential for including literacy and content in her instruction, her planning and instruction are still developing toward this goal. When asked to reflect on her planning for literacy and science, Debra replied, “I can see myself implementing more skill instruction into my lessons as I learn more about implementing NGSS.” As a beginning teacher, Debra has sought advice from more experienced teachers on her grade-level disciplinary data team. Veteran teachers aided Debra by providing activities and have collaborated with her in creating lessons. The support of colleagues has
guided Debra in her first years of teaching with varying degrees of disciplinary literacy use and NGSS alignment.

During initial observations, Debra planned and implemented lessons that were teacher-led and primarily focused on content delivery. Students were given instruction in a brief lecture before reading worksheet directions as a class and individually answering worksheet questions. Debra led each step of this process, including calling on students to share answers to the worksheet questions. Over the course of the nine weeks of observations, changes were evident in Debra’s approach. While still relying on worksheets to guide the teaching and learning process, classroom activities became focused on a problem or question that learning would prepare students to address. As Debra used problems or questions to drive instruction, opportunities for student participation and discourse increased. Debra gained experience and comfort with her students and NGSS which shifted her planning from a singular focus on content to a process that was more inclusive of practices and skills. Debra described this evolution of planning as she described planning in a final interview as including content and “thinking about the SEPs [science and engineering practices] my students will be practicing but also how I’m incorporating literacy.” This planning continued with colleagues in the development of assessments that included “student understanding in content and science skills, but also literacy.” Debra continued to develop in her understanding of NGSS and to develop pedagogy to support classroom instruction that engaged her students.

*RQ2: Reading.* When discussing reading in science class, Debra began with reading directions, whether in worksheets or inquiry activities. Debra stressed the need for students to understand what is to be done in activities and investigations. Beyond reading directions, Debra organized articles or brief readings to assist in building background knowledge. When reading
for information, Debra wanted students to develop both content knowledge and vocabulary. She directed students in studying in order to understand origins and meaning of vocabulary. For example, when introducing life science, Debra broke down the term biology, writing on the board “bio = life” and “-ology = study of” prior to defining the term for students. The strategy of breaking down words was drawn from her own experience as she said, “I found that this was a successful learning tool for me when I was a student, so that has influenced why I do it now as a teacher.” Being able to deconstruct words to determine meaning was useful for Debra, so she taught her students the strategy to assist them as they read for information.

One instructional approach attributed to Debra’s sole literacy course was the active reading strategy of “highlighting or underlining ‘big questions’ or important vocabulary while reading.” This skill was taught by Debra through direct instruction and modeling. When reading about and completing a worksheet on experimental design, Debra overviewed the process of marking the text and then modeled expectations on the first worksheet problem. Debra provided students with markings or codes shown in Table 4. to guide their marking of texts. As the first problem was read aloud by students, Debra modeled the marking of text on the interactive (SMART) whiteboard. The strategy of marking the text was intended to support students in what Debra called the process of “pulling information from their reading.”

Table 4

<table>
<thead>
<tr>
<th>Information</th>
<th>Definition for Students</th>
<th>Text Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Variable</td>
<td>What is changed or tested in an experiment</td>
<td>Straight Underline</td>
</tr>
<tr>
<td>Dependent Variable</td>
<td>What is impacted by independent variable or what is measured</td>
<td>Circle</td>
</tr>
<tr>
<td>Constant</td>
<td>What does not change in an experiment</td>
<td>Squiggle Underline</td>
</tr>
<tr>
<td>Control</td>
<td>Group without change in independent variable used for comparison</td>
<td>Box</td>
</tr>
</tbody>
</table>
The ability of students to gather information from text was only one component of reading identified by Debra. She also wanted students to be able to interpret and use information. Whether from traditional written texts, such as textbook chapters, print articles, articles from websites, or information provided in diagrams, charts, graphs, data sets, or video, Debra expected students to extract, interpret, and use information through reading these various sources. Debra structured opportunities for practicing reading skills. When studying cell division, Debra structured a web quest to answer the question, “How do cells divide?” She provided two required websites for students to visit, but Debra also allowed students to locate their own sites as long as evidence of the reliability and validity of sites could be provided. One of the required websites for the web quest was an animation of cell division processes. The use of the visual was considered by Debra to be a form of reading that required gathering and interpretation of information about the cell division processes of mitosis and meiosis.

The use of varying approaches to text, including animated descriptions of processes, was an intentional piece of instruction related to reading. As Debra planned for students to engage with content through reading, she wanted to be sure that all of her students could access content. Acknowledging her limitations pertaining to reading instruction, Debra attempted to assist students by providing texts at various levels. When planning, Debra would find articles at four different Lexile levels. She also tried to locate and present articles that included pictures or diagrams that assisted students in making sense of the reading. Approaches to text, such as directions, may also be varied by Debra to meet the needs of specific classes or groups of students. When preparing to complete an activity that requires a common set of directions, Debra described her differing approaches:
Some of my classes, as a whole, are also better readers than others. In my lower [reading level] classes, I’ll have a student read the directions to the class and we’ll underline important parts as they read. In my higher [reading] level class, I might have them read directions to themselves and then discuss what we’re doing with a partner. By providing different levels of text or using instructional approaches to a common text allowed Debra to support her students in obtaining, understanding, and using information from reading.

Although Debra linked reading directly to use in understanding directions and procedures, she used reading not only in directions, but also in accessing content information. Debra was up front about her limited background in literacy instruction and viewed this limitation as an obstacle in her instruction. Debra attended training sessions to improve instruction, mostly centered on understanding NGSS, and was willing to attend sessions to improve various components of her instruction, including literacy in science. While her reading instruction was limited to vocabulary and active reading strategies, she was cognizant of reading abilities and supports that could be offered through varied Lexile levels and structures of text that included diagrams, charts, graphs, and video. Debra used different levels and structures throughout her instruction as appropriate in providing content.

RQ3: Writing. In an initial interview, Debra stated a goal of including “writing in every lesson.” Most of the writing opportunities provided by Debra were short in duration and included answering questions, summarizing learning, or writing conclusions for activities. Debra used worksheets in lessons to guide students and to organize student work. These worksheets included open-ended questions that required written responses that did not need to be more than one to two sentences. Debra valued the written responses as a check-in or assessment of student understanding. Depending on the assignment, Debra would collect and read student answers or
she would use the student writing to initiate discussion, which will be presented in a later section on speaking and listening skills.

Writing was also used to summarize learning from readings. Summaries required writing more than one to two sentences. After reading an article about mutations, Debra used the one-pager format for summarizing. Students read the article and used active reading strategies of highlighting or underlining key points as previously modeled by Debra. After reading, students summarized their learning in a five-sentence written summary and a series of student-generated pictures to show key information learned in the reading. Debra also asked students to summarize information gathered from multiple sources. When completing a web quest on cell division, students visited different websites to answer questions and take notes on mitosis and meiosis. At the conclusion of the web quest, Debra asked students to summarize and compare the two processes. Summarizing required writing, which could be expressed through words and pictures.

Debra also used inquiry experiences to incorporate writing. At the end of activities, students would write about both processes and outcomes of the inquiry. The use of inquiry as facilitation and assessment of content and literacy was the focus of an inquiry activity developed by Debra and a grade level colleague. Debra describes the experiment and outcomes:

Students are given an experiment that relates to our content, for example, extracting DNA from fruit with detergent, and then are asked to find the problem, analyze data, make a conclusion supported with data, and offer improvements to the procedure and experiment. I can assess their literacy skills from the information they pull from the procedure/abstract and, from their conclusion, whether they can interpret the information and form a comprehensive statement.
Students were required to read and “pull” information but were assessed based on written evidence of understanding experimental methodology and science content.

Writing was viewed as a way for students to communicate understanding of science ideas. Debra provided numerous opportunities for students to write brief responses as answers to questions about science content. Summarizing was also used to bring together pieces of information from one or multiple sources. Writing conclusions for inquiry activities represented the third use of writing in Debra’s science classes. The majority of writing opportunities were short in duration, but conclusions allowed for writing that extended beyond a single paragraph response. Debra used writing as an assessment of both content knowledge and literacy skills used to obtain, evaluate, and communicate science learning.

*RQ4: Speaking and listening.* Speaking and listening skills were used in both small group and whole class discussions. Debra identified “using science talk moves when having discussions” as an important strategy learned at an NGSS professional development session. Using what she learned, Debra planned lessons that included points for discussions. Debra structured discussions based on articles, practice problems, worksheets, and inquiry activities. Each experience was intended to be a source of background information that prepared students for engagement on discourse about science ideas. This discourse allowed Debra to ask probing questions of small groups or to question and introduce ideas to the whole class.

Opportunities for speaking and listening in Debra’s class often stemmed from written responses. Worksheet questions were answered either individually or with a partner prior to being discussed as a whole class. The discussions were often teacher-led, beginning with a question and expecting an acceptable or correct answer. However, Debra did use discussions to probe student thinking by asking additional questions or seeking clarification. When discussing
experiments and variables, Debra initially seemed satisfied with student identification of key pieces of information from experiments, such as independent and dependent variables, constants, and controls. As students shared answers, Debra began to ask questions that required students to think deeper. When Debra asked, “What happens if Gary goes into the experiment thinking he knows what will happen?” she was able to direct the discussion to include ideas about bias, even differentiating this particular example as confirmation bias. In a separate class, Debra used student disagreement about validity of a presented experiment to introduce the concept of placebo effect. The ideas of confirmation bias and placebo effect were introduced by Debra when she felt it was the appropriate time based on discussions and student sharing of ideas.

Debra also used research and inquiry activities to initiate discussions. A web quest research project was completed with a partner. Debra encouraged student pairs to plan how they would research cell division. Partners then discussed the information they found prior to sharing as part of a whole class discussion. Inquiry lessons on the use of Punnett squares to predict potential offspring formed a foundation of experiences to support discourse on traits and inheritance. When discussing an activity Debra termed “the baby lab,” Debra asked questions to clarify student thinking. When a student responded that the answers were “not 100% accurate,” Debra replied, “How so?” The student explained that the answers were “guesses.” Debra probed by asking, “Are they random guesses?” to which student discussion arrived at the concept that Punnett squares demonstrate probabilities. Debra then continued facilitating a whole class discussion that required students to justify predictions and outcomes. Similarly, an experience extracting DNA from fruit was used by Debra to apply speaking and listening skills in the development of a better understanding of the process used in the extraction as well as conclusions about DNA in various fruits. The experiences planned by Debra provided
information that prompted discussion to both deepen understanding and introduce new science ideas as students began discussing known ideas or observations that allowed them to ask and respond to questions leading to new ideas.

Debra used speaking and listening skills to create opportunities for students to construct science knowledge. Based on shared experiences that included reading, practice, and inquiry activities, teacher-led discussions were planned and implemented. Student engagement in discourse with adequate evidence was an obstacle that Debra addressed through teacher guidance or facilitation of conversations. Throughout small group and whole class discussion, Debra posed questions to guide interactions with experiences and between students. As the observed unit progressed and included inquiry experiences and open-ended questions, students were able to respond to Debra’s prompts. Debra began to use talk moves to direct discussions to deepen student use of evidence and overall understanding of science concepts. She would routinely follow up student responses with questions including:

- Does anyone want to tell if they agree or disagree with the ideas? Why?
- How do you or what evidence supports your thinking?
- Who can build on what was just said?

The use of speaking and listening skills were often used to expand on student work, both written and hands-on inquiry experiences.

*RQ5: Science and engineering practices.* Debra stated that she had limited experience with NGSS but had “learned strategies at NGSS workshops and found them useful.” Working with colleagues to develop lessons and assessments that implemented the three-dimensional instruction outlined in NGSS was beneficial for Debra. She identified lessons co-developed with a grade level colleague as a means of integrating science skills, science content, and literacy
skills. Through both lessons developed with colleagues and on her own, Debra organized activities that engaged students in generating questions, investigating or critiquing investigations, analyzing data, using models, and using mathematical reasoning. Debra continued to practice and develop planning for and implementation of lessons that moved toward student-centered learning experiences incorporating science and engineering practices and literacy skills.

Debra used a problem or phenomenon to initiate student thinking and questioning. When discussing traits and inheritance, Debra used her dog as a phenomenon. The dog had several recessive traits and Debra asked, “How could my dog have the best chance to have offspring with the same traits as her?” She then presented three possible mates from the dog park and asked students what questions they had about the four dogs. Student questions were about which traits were dominant or recessive, traits of each dog, and phenotypes and genotypes associated with traits of the dogs. These questions were then used by Debra to guide the next steps of the lesson that included using Punnett squares as predictive models and mathematical reasoning as evidence in choosing a mate that would most likely result in offspring similar to Debra’s dog.

In the study of genetics, Punnett squares were used to make predictions in several activities and circumstances. Debra used worksheets with practice problems to introduce the predictive value of Punnett squares and the application of mathematical reasoning. An investigation guided by directions provided by Debra engaged students in determining outcomes of various traits in offspring. As students completed the activity, Debra circulated through the classroom and asked questions that prompted students to use evidence to support their answers. Debra would use questions, such as the following:

This is great, but how did you figure it out?

What do you know about the numbers and traits of offspring?
Look at the offspring again. Are any different from the others?

What does that tell you? How does this relate to the parents?

The use of Punnett squares to make predictions was one approach planned by Debra to aid instruction and support students in using mathematical reasoning, arguing from evidence, and answering questions or solving problems. When orally presenting arguments, students engaged in speaking and listening skills. Questions were answered through both speaking and listening as well as through written responses. Reading was used to access the information, including reading and interpretation of data from Punnett squares. The use of models in Debra’s classroom allowed students to engage in both literacy and science skills and practices.

The use of investigations in Debra’s classroom took two primary forms that included following given procedures and critiquing procedures and outcomes of given experiments. The investigative activities of cell division, traits, and inheritance were based on teacher-given steps to gather data. Investigating cell division included the use of online simulations and a guided modeling activity. In this guided activity, students followed a set of directions to use various supplies to represent cell parts and organelles throughout cell division. When studying DNA, students investigated DNA in different fruits, such as strawberries and bananas. Students extracted DNA, making and recording observations about the appearance and amount of extracted DNA. Prior to completing their investigation of fruit DNA, students critiqued a sample procedure and data, offering improvements to the procedure and explaining how the changes may impact the data. The critique of the sample procedure allowed Debra to assess student understanding and ability “to find the problem, analyze data, make a conclusion supported with data, and offer improvements to the procedure and experiment.” The different uses of
investigations and student responses enabled Debra to prepare students for completing their own experiment by addressing gaps in student skills and knowledge.

When students researched cell division, completed investigations, and argued from evidence, Debra was providing opportunities for students to collaborate. Partner or small group activities allowed students to share ideas and integrate evidence to support ideas. During these partner and small group discussions, Debra would circulate and the exchange of ideas by asking, “Why do you say that?” and “Do you want to add to that?” In whole class discussions, Debra drew on the “science talk moves” learned from NGSS workshops as previously described to guide student discourse. She would routinely follow up student responses with questions to probe for deeper understanding. The prompts represented new learning for Debra that she incorporated into her pedagogy. These “talk moves” elicited evidence from research and investigations and supported efforts to align with NGSS instruction and increase student participation in learning science.

Debra wanted her teaching “to develop reasoning skills in reading and inquiry.” The use of procedures to complete investigations used reading to facilitate inquiry. Although this inquiry was guided, Debra fostered skills for investigations through opportunities for critiquing experimental procedures and methods. Collaboration and discourse required evidence to support claims. Through questioning and what Debra referred to as “science talk moves,” she was able to probe for student understanding of content and practices in both small and large group activities. The use of science and engineering practices integrated components of literacy as used by scientists.

Conclusion. Debra identified a primary obstacle the implementation of literacy in science as her lack of training in literacy. Due to her lack of training and status as a beginning teacher,
Debra drew on methods that worked for her when learning as a student and strategies introduced to Debra through training about NGSS. Literacy was applied in activities that ranged from completing worksheets to inquiry activities and investigations. Responses on worksheets were not only examples of the use of writing but were often prompts for discussion that integrated the practice of speaking and listening skills. Debra’s focus on content delivery and assessment did not preclude the use of literacy in her instruction. Reading and writing skills were used to build background for discourse and inquiry, thus allowing the integration with science and engineering practices included in NGSS. Debra identified the need for additional learning about NGSS and literacy, viewing these future learning opportunities as important in the development of meaningful instruction. She viewed these opportunities for future development of PCK in science and literacy, which would support disciplinary literacy and NGSS-aligned instruction.

**Presentation of cross-case findings.** The cross-case analysis is divided into five sections. The first section compares the participants’ understanding of and training in disciplinary literacy and relationships to disciplinary literacy PCK. The second section compares participant uses of reading, writing, and speaking and listening skills in science instruction. The third section compares participant integration of science and engineering practices of NGSS with literacy in the science classroom. Overall successes, obstacles, and limitations of disciplinary literacy instruction are summarized in the fourth section. The final section presents general themes from the cross-case findings.

**RQ1: Understanding of disciplinary literacy.** Kaitlyn and Melanie had more experience and training in both the use of literacy in science and NGSS than Debra. The impact of various professional development opportunities resulted in an understanding of disciplinary literacy demonstrated in planned uses of literacy intentionally linked to science through skills and
practices. Melanie attributed her use of literacy to professional development received at a local university. Kaitlyn included collaboration with a grade level colleague as influential to her planning and implementation of literacy. The colleague with which Kaitlyn collaborates attended the same professional development as Melanie, thereby impacting Kaitlyn’s understanding and instruction through joint planning sessions. The PCK in disciplinary literacy for both Melanie and Kaitlyn was either directly or indirectly impacted by the development opportunity at the local university. The changes in PCK aligned literacy instruction with disciplinary uses due to the incorporation of science and engineering practices contained in NGSS and curricular expectations of the district.

In contrast to Kaitlyn and Melanie, Debra did not have access to the same professional development opportunities. Due to the timing of her date of hire in the district, Debra was not able to join the in-progress development offered at the local university. She also did not have common planning time with colleagues involved in the development program. Training offered by the district after Debra was hired has primarily focused on understanding the structure of NGSS and did not include aspects of disciplinary literacy. Because of minimal preservice coursework on literacy and lack of in-service focus on disciplinary literacy, Debra stated that her, “approach to teaching science and literacy is pretty minimal considering I don’t have much experience teaching literacy.” Explicit connections between literacy and science and engineering practices were not evident in Debra’s planning. While aspects of disciplinary literacy as explained in Debra’s within case results occurred in her instruction, she primarily focused her literacy planning on defining vocabulary and reading procedures of guided experiments. This narrowed focus of literacy in science differed from what appeared to be a seamless integration of
authentic literacy use demonstrated in the use of science and engineering practices by Kaitlyn and Melanie.

In addition to training, Kaitlyn and Melanie had prior teaching experience that aided the decision-making processes or PCK during both planning and implementation. Debra, only being in her second year of teaching, did not have a pedagogical base as broad as either Kaitlyn or Melanie. Debra did not appear resistant to developing pedagogical or content knowledge about literacy, stating, “I can see myself implementing more science skill and literacy instruction into my lessons as I learn more about implementing NGSS.” As a beginning teacher, Debra was more focused in what she described as, “how I’m going to explain the content and how I’m going to assess that they [the students] understand it [the science content].” Both Kaitlyn and Melanie were comfortable with the science content and use of literacy skills in science, thus allowing varied approaches not yet developed by Debra. Melanie remarked that “often the strategies to build content knowledge are also building literacy skills.” Kaitlyn offered a similar idea relating literacy in the expression of content when she said:

They [the students] have to have some literacy base to their science understanding to communicate it. It’s [literacy] crucial. It’s part of having students be able to interpret, whether it’s graphs, data. [or] text [to] gain new knowledge, utilize concepts learned in class and being able to share that, whether verbally, in writing, or in modeling.

Melanie and Kaitlyn transitioned from content area literacy approaches earlier in the year to the use of literacy as it would be found in the discipline. Their experiences with the content, skills, and practices provided a broad base of pedagogical resources which contrasted with Debra, who was in the early years of learning and constructing a pedagogical base.
In each of the three cases, development opportunities or lack of such opportunities resulted in differing approaches to literacy instruction. As two participants gained knowledge of NGSS and literacy, they developed PCK in science and literacy that embedded literacy as a component of what Melanie called “doing science.” These efforts emphasized skills relevant to the process of constructing and communicating science knowledge. While Debra was still developing PCK for literacy in science, she saw value in continuing to learn about ways to engage students in the use of literacy. With continued experience and professional growth opportunities, all three cases demonstrate the potential of developing PCK to address literacy and science content in ways that parallel uses by experts in the science discipline.

**Reading, writing, and speaking and listening.** The literacy skills of reading, writing, and speaking and listening were incorporated into instruction in the classrooms of all three participants. All three participants viewed literacy as an important component of science instruction as summarized in Table 5. Because of this participants’ stated importance of literacy skills, each participant planned for uses of literacy in the science classroom. In addition to a shared importance of literacy, all three participants also had views that expanded literacy beyond reading and writing of traditional texts. Participants viewed literacy as a process of obtaining and interpreting information in order to build or construct student knowledge. Drawing from the purposes of literacy for obtaining and interpreting information as described by participants and summarized in Table 5, the definitions of text included different uses in the science classroom. To meet the needs of student-centered learning experiences, participants identified the use of models, diagrams, tables, charts, graphs, data sets, and videos as text with which students would interact and interpret to obtain information. Similarly, information from various sources could be compiled and used to construct ideas that are communicated through writing that incorporates
traditional text as well as diagrams, tables, graphs, and other presentations of data and information. Finally, literacy includes the communication of ideas, which is important in a science classroom that is centered on student experiences, ideas, and understanding. Being able to talk about and defend current levels of understanding while also building knowledge that leads to deeper understanding can occur as students engage in both small and large group discourse.

Each of these components is visible in the participants’ science classrooms and demonstrate a bridge between disciplinary literacy uses and the construction of science knowledge.

Table 5

Summary of Participant Views on Literacy in Science Instruction

<table>
<thead>
<tr>
<th>Participant</th>
<th>Literacy View</th>
<th>Alignment with Disciplinary Literacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaitlyn</td>
<td>“It’s [literacy] crucial. It’s part of having students be able to interpret, whether it’s graphs, data. [or] text [to] gain new knowledge, utilize concepts learned in class and being able to share that, whether verbally, in writing, or in modeling.”</td>
<td>Expanded definition of text to include graphs and data used in science. Scientific modeling as a practice that incorporates literacy.</td>
</tr>
<tr>
<td>Melanie</td>
<td>“Literacy needs to be a means to be able to teach science. The literary pieces that are a part of science serve to be a delivery method for instruction…. More than ever before, I find myself embedding literacy into my content teaching with NGSS.”</td>
<td>Literacy instruction embedded in NGSS, including science and engineering practices.</td>
</tr>
<tr>
<td>Debra</td>
<td>“I think science and literacy teaching means that you’re teaching students to be critical thinkers and develop reasoning skills in reading and inquiry…. I can see myself implementing more science and literacy skill instruction into my lessons as I learn more about implementing NGSS.”</td>
<td>Literacy instruction increasing as understanding of NGSS improves, including science and engineering practices such as questioning and investigating.</td>
</tr>
</tbody>
</table>
**RQ2: Reading.** Reading was viewed as a means for gathering and interpreting information. In each classroom, students were asked to read traditional texts. This reading was often accompanied by a phenomenon-linked driving question for the unit to be either answered or at least addressed by the reading. While reading, Kaitlyn, Melanie, and Debra each asked students to code or mark the text. Initially, each teacher provided codes to use for desired information. In some instances, such as Melanie’s weekly assignment of articles, students were able to create their own codes or choose their methods for marking the text. After reading, students in each classroom were responsible for summarizing and sharing information learned.

The sharing of information represents writing or speaking and listening components of literacy, depending on the assignment and the use of the reading as planned by the teacher. The use of reading traditional articles was intentional by all three participants. Planning included both the timing of use of the article and the reading level of the article. For example, Kaitlyn was deliberate in the information presented as students learned about food webs, energy flow, and barn owl populations. She relied on student questions to determine when to present articles with relevant information. When choosing articles for use in class, Debra noted that she often chose articles of four different reading levels that presented the same content in order to meet the needs of her students. As each participant planned individual lessons and the overall progression of lessons, text played a key role in presenting pieces of information for students to use in understanding science ideas and concepts.

Traditional text was not the only source of information used in the science classes. Students were given diagrams, tables, charts, and graphs that also contained information. All three participants viewed these sources as text in science that required student attention to detail as they read and interpreted meaning from the information. This was summarized by Debra when
she said that diagrams, tables, charts, and graphs “are all used to display data, just as words can.” Similar to participants’ selection of traditional texts, alternative science texts were chosen at levels that could be interpreted by students and were introduced when questions required the additional information. The need for information could arise from student questions or from the logical progression of information that was necessary for continued learning of content. As students learned about components of ecosystems in Kaitlyn’s class, she used diagrams to relate the interactions of biotic and abiotic factors. When presenting human body systems, Melanie structured the study of systems in a way that presented a logical progression through the human body, but she also relied on student questions to guide the introduction of diagrams or data that helped students understand the systems. Debra’s instruction of genetics, she relied largely on the progression of understanding about traits, DNA, and inheritance to guide the use of data tables and Punnett squares. However, this pre-planned logical progression of instruction was built on a developing conceptual understanding that often aligned with student questions. In each example, the presentation of information was consistent with uses of tables, charts, graphs, and diagrams in the science discipline. Since these uses are consistent with authentic uses in the science discipline, they represent uses of disciplinary literacy in science instruction.

**RQ3: Writing.** Consistent with participant views that described reading as a means for gathering information, writing was considered a written form of communicating student knowledge and understanding, both as formative and summative checkpoints during instruction and at the conclusion of units or investigations. Writing was used in different ways depending on the goals of both teacher and student. After reading, each participant structured opportunities for students to write summaries of reading or answer questions based on information presented in a reading. Participants also used written questions, summaries, or conclusions as components of
inquiry-based activities. In addition to the use of written word, writing was also incorporated through the creation of models, graphs, charts, and diagrams.

The use of written text was evident in summaries written about articles and activities. Both Melanie and Debra used a format called the one-pager to organize written and visual summaries of information. Kaitlyn also asked students to write summaries based on reading but did not use the one-pager template. Kaitlyn did offer structure for the summaries, such as through the use of two-dollar summaries described in the within case results for Kaitlyn. The participants also used writing to respond to questions or to write conclusions of activities completed in class. The duration of writing in these opportunities was primarily short, with the focus on presenting a synopsis of learning. These pieces of writing may be viewed as formative when applied to the progression of the unit or as summative pieces at the end of an activity.

The use of models presented a different form of writing that integrated written word through captions or labels along with visual representations and data to support explanations of a phenomenon. The use of modeling was prevalent in the study of human body systems in Melanie’s classroom. Students worked in groups to study and represent the processes of selected body systems identified by the Grade 7 science curriculum. Each system was modeled individually prior to Melanie presenting the phenomenon of the human body that required the integration of systems. Students presented current levels of understanding through their models and included pictures, data from activities, and information from research as supporting evidence for how the system functions and the importance of the system to the body. Similarly, Kaitlyn used student-developed models to represent interactions and connectedness in food webs and energy flow through ecosystems. Students added to or revised these models as information was learned from articles, activities, and discussions. Both Melanie and Kaitlyn used models as long-
term writing assignments that included collaboration and feedback that led to revisions of ideas and revisions of presentation. The use of models was observed in Debra’s class as well, but students’ models were not used to make and defend predictions. The writing associated with models in Debra’s class was shorter in duration than the use of models by facilitated by Kaitlyn and Melanie. However, students in Debra’s classes were given a phenomenon, such as Debra’s dog and its offspring that required the use of the model as evidence in a written and oral explanation of predictions. All three participants considered the uses of models as writing and were implementing such uses due to training associated with NGSS and the use of modeling as a science and engineering practice.

*RQ4: Speaking and listening.* Speaking and listening skills are included as literacy practices in CCSS and are therefore part of the conscious planning efforts of all three participants. When learning about NGSS, the participants also noted the inclusion of discourse which aligned components of science instruction with literacy. Speaking and listening skill development was incorporated into discussions of or discourse on science ideas, the use of evidence to support these ideas, and scientific argumentation between peers. One commonality of different trainings on NGSS noted in responses of each of the participants was the use of certain phrases or question stems that could prompt deeper thinking, collaboration, and the building of knowledge through a communal sharing and challenging of ideas. Debra referred to these phrases or question stems as “science talk moves” that can allow for the facilitation of discussion (Michaels & O’Connor, 2015). As teachers used this approach to build an environment of discourse, the use of guiding phrases and questions became less teacher-centered as students gained experience with and confidence in their ability to engage in discussions.
Participants built speaking and listening skills through both small group and whole class discussion of science ideas and use of evidence.

**Conclusion.** All three participants embedded disciplinary literacy approaches in the instruction of science content. Reading, writing, and speaking and listening skills were embedded in ways that fostered literacy use as it pertained to science. Instruction included traditional uses of reading to decode information in written texts, but also included opportunities for students to “read” other forms of text that included diagrams, tables, charts, graphs, and data sets consistent with Norris and Phillips (2003). The use of these alternative forms of text required students to read and interpret information presented in forms other than the use of written word. Similarly, writing included both traditional approaches, such as summaries, conclusions, and open-ended responses, as well as methods that incorporated visual and written components, such as models and visuals to support summaries. In addition to reading and writing, all three participants structured opportunities for discourse that progressed from more teacher-led to student-centered as both teacher and student skills developed (Michaels & O'Connor, 2015).

**RQ5: Science practices.** Science instruction in the participants’ district was being impacted as preparations were being made to meet newly adopted science standards. While the writing of new curricula had not been completed, certain aspects of instruction were being changed in preparation for future implementation of NGSS. Using existing curricula, participants were developing pedagogy to integrate science and engineering practices and crosscutting concepts outlined in NGSS into instruction. These initial changes to instruction allowed participants to begin changing pedagogy with familiar content. One change in pedagogy was the re-emphasis of literacy as applied to the science discipline. As participants engaged in aligning
instruction to the three-dimensions of NGSS, they had a positive view of literacy connections within content instruction in the form of disciplinary literacy.

Participants were at various stages in their development of pedagogy for incorporating these practices and concepts, but all acknowledged the impact on literacy instruction. Debra was the participant least experienced with the NGSS dimensions of crosscutting concepts and science and engineering practices. In her development of understanding NGSS, Debra found NGSS workshops as sources of “useful ways to incorporate speaking, listening, and writing skills.” She also believed that further learning would result in her incorporation of “more science and literacy skill instruction into my lessons as I learn more about implementing NGSS.” Debra was able to see positive impacts of NGSS on literacy instruction as literacy becomes more authentic to the processes or practices of the science discipline. Kaitlyn and Melanie had more opportunities to learn about and begin to assimilate practices from NGSS into classroom instruction. Both Kaitlyn and Melanie specifically mentioned the impacts of NGSS on their practice and in the approach to literacy instruction in the science classroom. For example, Kaitlyn described how she has rethought the meaning of literacy in science. Instead of reading an article and highlighting information to introduce a topic, Kaitlyn used visuals to initiate student thinking and set the course for future investigations that drew on disciplinary literacy skills. Kaitlyn was enthusiastic as she explained:

I just did a visual initiation where they [students] had to look at a flowing river and had to make observations about that river: River 1, River 2, and River 3. And all three rivers were different degrees, like stream, medium river, large river, and they had to talk and compare what the rivers had in common and what made them different. So, using visual cues, for some of the students it helps them understand.
Kaitlyn related that students were more engaged, and she anticipated greater literacy use than when she has used traditional text to introduce the topic. She attributed this expectation to instruction centered on student questions and students’ commitment to investigating and answering these questions.

The science and engineering practices included in NGSS aided participants in implementation of literacy through activities consistent with the uses of literacy by experts in the discipline of science. As participants became more familiar with NGSS, the use of literacy became more easily embedded. Kaitlyn was initially skeptical of the process of integrating literacy through instruction aligned with the three dimensions of NGSS. However, at the conclusion of the observed unit, she was enthusiastic in her descriptions of the reading, writing, and speaking that her students utilized throughout their explorations of barn owl populations that included ecosystems, interactions such as food webs, and energy flow. In her work, Melanie found the integration of literacy to be easier through instruction consistent with NGSS, remarking that the incorporation of literacy was becoming “second-nature” in her planning. Viewing literacy as it is used in science assisted all three participants in developing instruction that used literacy in science and represented disciplinary literacy in science and engineering practices.

**Common successes, obstacles, and limitations.** Successes of disciplinary literacy instruction were observed in all three cases. Each participant used a degree of content area literacy instruction to ensure student capacity in engaging with literacy practices and science content. Content area literacy instruction was typically presented as teachers modeled or guided students in the skill prior to releasing students to practice. While content area literacy skill instruction was observed, the primary uses of literacy were authentic application of skills to
science learning. Students took skills and used them to gather and interpret information to find necessary pieces for constructing knowledge about science to address a phenomenon or driving question. The use of literacy in what Melanie called “doing science” moved away from content area literacy and toward disciplinary uses of literacy resulting in literacy skill use that was meaningful and engaging for students. Furthermore, re-emphasis of literacy skills as they are used in the science discipline aligned with participants’ understanding and implementation of NGSS. As participants utilized approaches consistent with the three-dimensions of science teaching presented in NGSS, all three participants connected content and literacy instruction in meaningful, authentic ways. As literacy fit into science instruction, participants did not see disciplinary literacy instruction as a separate piece of instruction that was added on to content instruction. Instead, Melanie summarized NGSS and literacy instruction when she said:

More than ever before, I find myself embedding literacy strategies into my content teaching with NGSS. For example, we often gather information from content specific articles or activities to not just aid our learning, but often to start a topic and/or add to it [topic or content learning].

At the end of using NGSS crosscutting concepts and science and engineering practices as part of content instruction, Kaitlyn and Debra had similar views on the use of disciplinary literacy as part of content instruction in NGSS. While Kaitlyn expressed initial concerns about NGSS lacking literacy instruction and Debra was unsure about literacy instruction due to a lack of training, experiences using literacy as pertaining to the discipline led to positive views of integration of literacy in science content instruction. Each participant was successful in planning and structuring opportunities for students to use literacy that reflected uses of literacy by experts within the science discipline.
Obstacles. While participants were successful in creating opportunities for disciplinary literacy use within the science discipline, they also identified common obstacles that needed to be addressed in the design and implementation of instruction. Kaitlyn described the process as "overwhelming and complex" and included a compilation of participant issues such as the amount of time necessary for student-centered instructional approaches, building student capacity or agency for meeting expectations, and building environments supportive of student risk and failure. Time is a common classroom concern, which participants identified as an even greater concern with changes in instruction to meet expectations of NGSS. Debra conveyed the need to know students in order to "plan lessons for classes that are themselves very diverse," all of which require time. In some instances, activities and pedagogical approaches were being utilized by participants for the first time. When planning, participants needed to maintain a degree of flexibility to account for an uncertainty of timing. For example, activities that included discussion may take a longer or shorter amount of time depending on the group of students, topic being discussed, and level of understanding demonstrated by students. More time may be necessary to probe student misconceptions to aid teacher understanding that could be applied to determining the next steps. Melanie experienced classroom discussions that took more time than she had planned. When discussing the role of the digestive system, student presentations and discussion took longer than anticipated. Melanie allowed the discussion to occur and did not impose an endpoint based on time as she felt the discussions were beneficial for students. As class was ending, a student pointed out that the class did not accomplish all of the items on the agenda for the class, to which Melanie responded, “We were having a productive discussion about the importance of the digestive system. We will come back to those other points next class.” This demonstrated a flexibility in planning that was responsive to student needs and
applies to disciplinary literacy as the time was used to engage in speaking and listening skills that deepened student thinking and understanding.

Kaitlyn and Debra also experienced such shifts in instructional planning as they prepared for instruction that was increasingly centered on the needs of students. Both Kaitlyn and Debra described variations in classes that could impact the progression of instruction within and between lessons. Kaitlyn stated that planning for and implementation of literacy and science content instruction changes “every day, every period.” She knows the needs of students in each class and plans activities to meet student needs by either allowing students to engage independently in practices with which they are comfortable or by structuring supports to aid in developing areas that are in need of improvement. Kaitlyn focused on building the agency of her students so they could be successful in learning science. Such planning does not allow a “one size fits all” approach and moves beyond general strategies to application within the science discipline and included planned instruction to meet the needs of different classes and even different groups of students within the same class. Similarly, Debra said she decides on which approaches are “more appropriate” based on her knowledge of the students in a particular class. Even when implementing the same lesson in multiple classes, Debra’s approach changed between each class. Certain groups of students were more adept at engaging in discourse and therefore needed fewer guiding questions from Debra, but other classes lacked confidence and sat quietly until prompted by questions from Debra. In each class, Debra responded to the needs of the students to engage students in discussion. Not knowing or understanding the areas of strength, class personalities, or group tendencies represents an obstacle that could impact the timing and flow of a planned lesson as well as overall student learning. Being able to recognize the needs of a class and respond accordingly to build student agency relies on a PCK that
includes the ability to respond in planning for and implementation of learning opportunities for literacy and content in the science classroom.

In addition to literacy and content instructional time in the science classroom, disciplinary literacy instruction requires a classroom environment that is supportive of students taking risks in sharing ideas and engaging in activities that may require revisions. Such an environment must allow for students to fail and then revise thinking to construct understanding of science ideas. Debra believes this process began early in the school year through ice breakers. She said that:

In the beginning of the year we had a lot of small group and whole class discussions as ice breakers, which helped set the foundation for positive discourse. So, students know the correct way to respond to peers and introduce their own ideas.

Kaitlyn also began building a supportive classroom environment at the beginning of the year. She builds rapport and trust with students by making their learning personal to her. The process of establishing the classroom environment begins with:

that comfortable zone of expectations that we are all here as learners. We’re all here to make mistakes, to grow. It’s setting that tone at the beginning that there is no laughing, no one is good at everything. It’s building through personal stories, sharing examples with the kids. So, when we change seats now, there’s no [sigh sound] or eye roll because they know I’m going to call them right out and say, “Well, if that were my kid, you really hurt my feelings.” It makes it very personal to them. They want to take a risk. They want to share answers or talk to their group or jump into the conversation.

All three participants had established a classroom environment that allowed students to be comfortable in sharing ideas and engaging with peers. The creation of environments supportive
of student engagement, risk-taking, and failure are important in reflecting the practices and 
processes of science and therefore allow the application of disciplinary literacy in ways that 
parallel uses within the science discipline.

Obstacles to disciplinary literacy instruction in science can be overcome as demonstrated 
by flexibility in planning and the establishment of supportive, authentic learning environments. 
However, limitations impacted participant abilities to implement disciplinary literacy instruction. 
Melanie identified limited training in literacy instruction during her preservice experiences. She 
was able to overcome this limitation through various in-service development opportunities but 
did not identify a significant learning opportunity until her recent engagement in development 
offered through a local university. Similarly, Debra only had a single course on literacy 
instruction throughout her undergraduate and graduate programs. Now, as a second-year teacher, 
Debra believed that her limitations in training impact her current levels of instruction. Much as 
Melanie sought development opportunities throughout her career, Debra identified a current need 
for development in the areas of literacy and NGSS implementation in the classroom. Knowledge 
pedagogical approaches to teach literacy and content are necessary to create meaningful 
classroom uses and experiences. If opportunities for training are limited, implementation of 
disciplinary literacy and science content instruction will be incomplete.

Limitations. In addition to training, limitations were presented in inadequate opportunities 
to develop PCK and practice instructional techniques. This was represented by Kaitlyn’s initial 
stance that, “NGSS seems to waiver with its literacy support on when and where to label the 
correct terminology over the concepts being taught.” Kaitlyn felt that there was a lack of balance 
between literacy and science content. When considering Kaitlyn’s prior training, the focus of 
literacy instruction in science had been on content area literacy instruction. Kaitlyn no longer
saw opportunities for incorporating generalized strategy instruction in science lessons. However, after teaching a unit that focused on the instruction through the three-dimensions of instruction outlined in NGSS, Kaitlyn identified opportunities that allowed students to practice and build literacy skills. She viewed the unit as an important component in developing both science content and literacy skills that would allow students to “explain their [students’] thinking better as they [students] use these [science and literacy] skills.” Kaitlyn’s understanding of disciplinary literacy instruction was impacted by the opportunity to practice and apply various pedagogical approaches in her science teaching. Similarly, Kaitlyn and Debra developed appreciation for the implementation of disciplinary literacy as they practiced skills learned in professional development workshops. Opportunities to implement and practice learned pedagogical approaches allowed participants to refine pedagogy and to more fully grasp the relationships between disciplinary literacy and science content instruction.

**General themes from cross-case findings.** Four general themes were developed from the cross-case findings. The first three themes from the findings of the study included planning and implementation of literacy, impacts of a professional development experience, and simultaneous transitions to disciplinary literacy and NGSS. The final theme presents unexpected or discrepant data. These general themes will be presented as related to the findings of the three case studies.

*Planning and implementation of literacy.* Participants planned for implementation of literacy instruction in the science classroom. District and school goals aligned with teaching literacy across subject areas facilitated teacher consideration of literacy, but prior training focused primarily on generalized content area literacy instruction. Initially, the transition to science instruction aligned with NGSS caused some concern, specifically for Kaitlyn, as content area literacy practices did not fit with new learning about three-dimensional instruction as
outlined in NGSS. Views of literacy, specifically reading and writing, broadened as participants considered student literacy needs in science as a result of learning about NGSS.

Participants’ broadened views of reading and writing incorporated definitions of text and options for writing that expanded beyond written text. Participants planned for and implemented learning opportunities that included reading, writing, speaking and listening, and science and engineering practices. Within each of these components, practices are organized by frequency of use as shown in Figure 4. Participants identified reading as a means of obtaining and interpreting information. Writing and speaking and listening were identified primarily as means of communicating understanding, but also aided students in constructing science knowledge. Science and engineering practices were present in instruction as supports for obtaining and evaluating information, analyzing data, communicating and defending ideas with supporting evidence.

**Figure 4.** Practices organized by frequency of use within each component of literacy used by middle school science teachers

*Impact of professional development.* Views on literacy in science from two participants, Melanie and Kaitlyn, were linked both directly and indirectly to an NGSS professional
development experience offered at a local university. The professional development experience was not a consideration for participation in the study but was referenced by Melanie and Kaitlyn. Melanie was directly involved in the professional development as a participant. Kaitlyn was not directly involved in the development opportunity but benefited from the experience as she collaboratively planned with a grade level colleague that attended the professional development experience. Learning from the development experience is summarized in Table 6.

Table 6

*Impacts of Professional Development Experience on Melanie and Kaitlyn*

<table>
<thead>
<tr>
<th>New Learning</th>
<th>Impact on Practice</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Literacy Strategies</strong></td>
<td>Learning of multiple literacy strategies that are authentic to the science discipline, including jig-saw activities, use of current articles to expose students to vocabulary</td>
<td>Reading to promote questioning and investigation</td>
</tr>
<tr>
<td><strong>Science Practices</strong></td>
<td>Deepen understanding of science skills and practices, such as scaffolds for analyzing scientific data and reports</td>
<td>Integration of literacy instruction in science and engineering practices instruction and application</td>
</tr>
<tr>
<td><strong>Embedded Strategies</strong></td>
<td>Authentic uses of literacy in science</td>
<td>Support analyzing and interpreting data, modeling, arguing from evidence, and explaining ideas</td>
</tr>
<tr>
<td><strong>Curriculum Development</strong></td>
<td>An understanding of methods for structuring lessons that allow students to engage in science through literacy</td>
<td>Planning for experiences that integrate literacy instruction in science and engineering practices instruction and application</td>
</tr>
</tbody>
</table>

*Simultaneous transitions to disciplinary literacy and the NGSS.* Literacy instruction in the science discipline has been part of teacher planning and implementation at the selected site due to school and district goals centered on literacy achievement of students, particularly in the areas of reading and writing. Two participants, Melanie and Kaitlyn, were veteran teachers at the
school and therefore had experience with the emphasis on content area literacy instruction. As participants learned more about instruction aligned with NGSS, they reacted to perceived opportunities and challenges presented in curricular expectations stemming from NGSS. Once participants engaged in implementing instructional units aligned with the expectations of three-dimensional instruction in NGSS (NGSS Lead States, 2013), the use of disciplinary literacy instruction became more evident.

*Unexpected or discrepant data.* The study focused on the implementation of disciplinary literacy instruction in middle school science classrooms to explore teacher planning and implementation. Shulman (1986, 1987) presented that prior experience and training can impact PCK. During this study, teachers with the most experience were also impacted by recent opportunities for professional growth. This was unexpected as the novice teacher had not experienced disciplinary literacy in preservice coursework. The impact of prior teaching experience cannot be completely extracted from impacts of professional learning opportunities.

Interview questions allowed participants to explain the impacts of both experience and training to aid in the description of approaches to disciplinary literacy instruction in science.

While observing different classes engaging in the same lesson plan, teacher presentation may have been consistent with differing outcomes due to student reactions and readiness to participate in planned activities. Observations were made based on the interactions of participants with students. To address discrepant data, interview questions followed up to address instructional variations based on student readiness. Participants were asked about reactions of students or groups of students and the response associated in various lessons. Data from interviews were used to further explore and explain observations.
Analysis of Findings

This study was an exploratory investigation of the implementation of disciplinary literacy instruction in science classrooms. The overarching research question, “What do science educators in an urban middle school know about and do to implement disciplinary literacy instruction in the science classroom?” established the focus in exploring and analyzing results. Five research sub-questions focused on various components of disciplinary literacy and science instruction. Participants representing different grade levels and experiences provided an opportunity to explore varied perspectives of disciplinary literacy implementation in science classrooms. Analysis of the findings are presented as organized by the research sub-questions.

RQ1: Disciplinary literacy knowledge, training, and development experiences. The first research sub-question addressed participant understanding and training related to disciplinary literacy as stated, “What are prior disciplinary literacy knowledge, training, and development experiences of science educators?” Daehler, Heller, and Wong (2015) and Park et al. (2011) report that PCK can be developed or improved through professional learning opportunities. Consistent with the literature, participants demonstrated impacts of professional learning on PCK and therefore on instruction (Daehler et al., 2015; Park et al., 2011; Roseler & Dentzau, 2013; Zhang et al., 2015). The impacts were prominent in the planning and instruction of Kaitlyn and Melanie as they were influenced by a development opportunity provided by a local university. The development experience focused on transitions to NGSS that included literacy. Melanie was a participant in the professional development and therefore experienced learning activities first-hand (Buczynski & Hansen, 2010). While Kaitlyn did not attend the professional development, she worked closely to collaboratively plan with a grade level
colleague that attended the training. Both Melanie and Kaitlyn drew on learning to improve instruction of science and disciplinary.

As an active participant in the professional learning experience, Melanie was able to identify uses of literacy in her planning and implementation of science instruction. This application of learning represented the development of the content knowledge construct of PCK identified by Shulman (1986, 1987). The understanding of literacy uses was content that Melanie could apply to her planning of instruction. Melanie believed that literacy encompassed many different forms and actions. Literacy in Melanie’s view included an expanded definition of reading to include interpreting graphs and data sets as well as reading, writing, and discourse centered on scientific modeling representing an expanded understanding of the content of literacy (Shulman, 1986, 1987). Melanie was able to move from scholarship or learning about disciplinary literacy to thoughtful planning and implementation consistent with the progression overviewed by Shulman (1998). Simultaneous learning about approaches to aligning instruction with NGSS expectations and disciplinary literacy resulted in Melanie connecting science instructional reforms and disciplinary literacy combining knowledge of content, disciplinary literacy, and pedagogy (Park & Oliver, 2008).

Kaitlyn did not directly engage in the professional development experience but did cite her work with a grade level colleague as “influential” in her ability to implement disciplinary literacy instruction. Although she did not directly engage in professional development as outlined in research, the experience of collaboration impacted Kaitlyn’s view of pedagogy that allowed her to integrate literacy in science instruction (Buczynski & Hansen, 2010; Daehler et al., 2015; Park et al., 2011; Roseler & Dentzau, 2013; Zhang et al., 2015). Co-planning with her
colleague allowed Kaitlyn to gain insight for supporting literacy in science instruction, even with
instructional adjustments aligned to NGSS.

As Park et al. (2011) suggested, the development of Kaitlyn’s PCK began with key
contcerns about reforms to science instruction. Kaitlyn initially questioned efforts to incorporate
disciplinary literacy instruction in science classrooms moving to alignment with the NGSS.
While Kaitlyn developed an appreciation for disciplinary literacy instruction through
collaboratively planning, a deeper understanding developed as she implemented the planned
lessons. Collaborative planning allowed Kaitlyn to develop an understanding of curricular
connections to disciplinary literacy within science consistent with the presentation of curriculum
as a construct of PCK in the work of Grossman (1990). As Kaitlyn described her approach to
introducing a subsequent unit using interpretation of data, she demonstrated an understanding of
disciplinary literacy that was becoming integrated into her practice as a component of her PCK
(Shulman, 1998).

Both Melanie and Kaitlyn viewed the teaching and use of science and engineering
practices as opportunities for disciplinary literacy instruction as influenced by professional
development (Buczynski & Hansen, 2010; Daehler et al., 2015; Park et al., 2011; Roseler &
Dentzau, 2013; Zhang et al., 2015). The teaching and use of literacy progressed from structured
delivery and practice to strategies to application of literacy in science practices consistent with
disciplinary literacy as defined by McConachie (2010). This progression of instruction
represented developing PCK consistent with the research of Shulman (1986, 1987). As Melanie
and Kaitlyn drew from content and literacy training to view literacy as an essential component in
learning science and engaging in science practices, they employed evolving pedagogy
(Grossman, 1990; Park et al., 2011; Shulman, 1986, 1987). Such an approach is consistent with
the suggestion of Norris and Phillips (2003) that fundamental literacy is essential for derived literacy, such as content, and that text can be varied forms in science, including charts, graphs, diagrams, and data sets. Through Learning and professional development, Melanie and Kaitlyn refined their PCK to implement disciplinary literacy instruction in science (Shulman, 1986, 1987).

In contrast to Melanie and Kaitlyn, Debra had neither an opportunity to receive training nor the chance to collaborate with someone who received training. Additionally, as a beginning teacher, Debra relied primarily on preservice coursework and personal experiences as a student due to a lack of classroom experiences, which fits with Shulman’s (1986, 1987) theory of PCK.

The approaches learned and implemented by Debra were primarily based on generalized strategies for decoding text, understanding information, and defining vocabulary. Debra did not have experience as a teacher to provide a broad base of pedagogical knowledge or practice, therefore impacting PCK (Shulman, 1986, 1987), especially in the area of disciplinary literacy. For these reasons, uses of literacy by Debra focused on students understanding directions and communicating answers. While Debra’s planning for literacy use centered on reading directions and writing answers, she was also learning about the structure of NGSS and addressing the use of science and engineering practices in her lessons. The incorporation of science and engineering practices broadened Debra’s view of literacy and, similar to Melanie and Kaitlyn, she identified the use of text to include graphs, charts, diagrams, and data sets. Uses of disciplinary literacy linked to these various sources of text were included in planning but were not explicitly linked to literacy and were more focused on science content.

When considering the work of Stage, Asturias, Cheuk, Daro, and Hampton (2013), NGSS implementation provides opportunities for literacy instruction as reflected in the intentional
pedagogical choices of teachers such as Melanie and Kaitlyn. An understanding of disciplinary literacy as related to implementation of instruction aligned with expectations of NGSS positively impacted PCK development through the development of science pedagogy as demonstrated by Melanie and Kaitlyn (NGSS Lead States, 2013; NRC, 2012; Park & Oliver, 2008; Shulman, 1986, 1987). Both through first-hand experiences and collaboration, Melanie and Kaitlyn were able to intentionally connect science instruction with uses of literacy consistent with uses in science resulting in the development of a disciplinary literacy PCK (Shulman, 1986, 1987, 1998).

Professional development and collaboration provided a common, broader definition of literacy with opportunities for finding and using a wide array of texts (Anderson, 1999; Fisher & Ivey, 2005; MacMahon, 2014; Tang, 2016; Vellom & Anderson, 1999). This common language, understanding, and connections to NGSS resulted in Melanie and Kaitlyn being willing and able to embrace disciplinary literacy instruction as part of the transition to instruction aligned with three-dimensional science learning (NGSS Lead States, 2013; Stage et al., 2013).

While disciplinary literacy was implemented through the use of science and engineering practices, teacher pedagogy had not shifted entirely to a disciplinary literacy focus. All teachers used content area literacy strategies such as marking the text and writing summaries (Fisher & Ivey, 2005; Herber, 1970). The teachers also structured opportunities for students to engage in disciplinary literacy instruction through activities that included the creation of scientific models, investigations, and discourse in the science classroom ((Berland & Reiser, 2008; Drew & Thomas, 2018; Michaels & O’Connor, 2015). Rather than implementing instruction that focused on either content area literacy or disciplinary literacy, the participants used different modes of literacy instruction dependent on the use and intended outcomes of the lesson. Therefore,
instruction in the three observed science classrooms fit with the recommendations of Brozo et al. (2013) and Faggella-Luby et al. (2012) who included balancing content area and disciplinary literacy needs and instruction.

Consistent with Shulman’s (1986, 1987) discussion of PCK, disciplinary literacy PCK was supported by both learning opportunities and an accumulation of classroom teaching experiences. Melanie and Kaitlyn were able to draw from years of teaching experience to adapt PCK based on new learning about disciplinary literacy and changing science standards (Daehler et al., 2015; Park et al., 2011). However, Debra did not have years of classroom experience upon which she could reflect and modify. She therefore incorporated strategies from her coursework focus on content area literacy strategies with incidental rather than intentional integration of disciplinary literacy practices. Overall, the level of understanding of both disciplinary literacy and science content instruction impacted participants planning and implementation of learning experiences inclusive of literacy and science (Park et al., 2011; Park & Oliver, 2008; Shulman, 1986, 1987, 1998).

**RQ2: Reading implementation in science.** The second research sub-question focused on the components of reading in literacy instruction and what science educators at the urban middle school do to implement science instruction that supports learning and use of reading skills. Reading was viewed similarly by all three participants as they viewed reading as a process of gathering information and interpretation. Using reading to gather information in science relied on a broader view of text that included more than written word. Consistent with Anderson (1999) and Norris and Phillips (2003), all three participants stated that texts for reading and interpreting include diagrams, charts, graphs, and data sets in addition to written word. However, Melanie
and Kaitlyn used reading embedded in ways authentic to the uses in the science discipline as recommended by Rupley (2010).

Prior to embedding reading in science instruction, students needed to be engaged in the process of reading as applied to science texts, which included approaching texts as sources of information. Reading as presented by Anders and Guzzetti (2005) and Clinton and van den Broek (2012) included interpretation and analysis of information that could foster application in science. This was consistent with the views of participants that reading was a means for gathering and interpreting information. Prior to disciplinary uses of reading, an understanding of processes to access information was important. As Brozo et al. (2013) and Faggella-Luby et al. (2012) report, there needs to be a balance of content area and disciplinary literacy instruction. This was evident as all three participants used content area literacy instruction early in units to establish skills in using science text. Participants used active reading strategies that aided students in marking text, questioning, and noting information prior to activities that engaged students in engaging in scientific practices (Fisher & Frey, 2008). Pedagogical knowledge was developed as the participants identified and implemented a range of literacy instruction that progressed from content area to disciplinary literacy instruction (Brozo et al., 2013; Faggella-Luby et al., 2012; Shulman, 1986, 1987).

To aid students in moving from content area strategies to disciplinary uses of literacy, Melanie used weekly reading assignments in her class to either stimulate interest in upcoming topics or to address interests resulting from investigations or discussions (Fisher & Frey, 2008; Houseal et al., 2016). These reading assignments were more than practice in decoding and comprehension as they served as activities that spurred scientific practices, such as questioning, discourse or argumentation with evidence, and scientific investigations to gather and analyze
additional data (NGSS Lead States, 2013; Yager, 2004). Student interests were a key consideration in the selection and assignment of articles. The incorporation of student interest to drive instruction represented the application of knowledge of students as a factor in developing PCK (Shulman, 1987). This use of knowledge of students and student interest fit with the application of reading instruction in science to stimulate interest (Enfield, 2014; McClune et al., 2012).

While Kaitlyn did not assign articles as part of a weekly routine, she provided traditional texts when appropriate for student learning. Much like Melanie, Kaitlyn provided relevant articles to either stimulate interest or respond to student questions, interests, or desire for more information relevant to a scientific phenomenon (Fisher & Frey, 2008; Houseal et al., 2016). For Kaitlyn, planning the use of reading followed authentic needs that promoted inquiry and use of science practices (Lemke, 2004; Yore, 2004). The stimulation of interest represents pedagogical knowledge while the focus on authentic needs of the discipline represent content knowledge and educational goals. The interactions of pedagogy tied to interests and content of authentic and necessary science and literacy learning are consistent with Shulman’s (1986, 1987) PCK.

Reading was used by Melanie and Kaitlyn to structure opportunities for students to interact with science in ways that could drive science practices in the classroom. The use of reading represents pedagogical knowledge and choices that inform PCK (Shulman, 1986, 1987). Melanie used the weekly articles to provide current, relevant information about the topics studied in science while Kaitlyn used articles to fill in gaps in understanding and to allow students to develop questions for investigations. These uses did not preclude the use of science practices that included questioning and investigation but allowed students to have information that enhanced the use of practices. As science instruction progressed through the unit, lessons did not focus on
strategies for reading, but on how the reading informed student practice as scientists (Anders & Guzzetti, 2005; Fang & Coatoam, 2013; Piercy & Piercy, 2011; Rupley, 2010; Shanahan & Shanahan, 2008; Yager, 2004; Yore, 2004). Debra used reading to analyze and apply science information but did not plan for disciplinary uses of reading to drive science practices outside of following a written procedure for investigating content.

Reading was used by all participants to gather information from a variety of sources. Consistent with Lemke (2004), Norris and Phillips (2003), and Vellom and Anderson (1999) all three participants considered charts, graphs, and diagrams as text, leading to gathering information from these sources as a form of reading in science. Once students accessed information in a variety of forms, they were often asked to use the information in an explanation through modeling or discourse or in planning an investigation. When asked to use information, participating teachers were developing student-centered opportunities for applying disciplinary learning through practices that support the construction of science knowledge (Anders & Guzzetti, 2005; Clinton & van den Broek, 2012; Enfield, 2014; Linderholm et al., 2014). Kaitlyn reported the transition of instruction to student-centered approaches as a shift in her pedagogy, thus impacting her PCK and how she presented science content to students (Park et al., 2011; Shulman, 1986, 1987).

**RQ3: Writing implementation in science.** Writing in science instruction was the basis of the third research sub-question, “What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of writing skills?” Limited uses of extended traditional writing activities, such as essays and lab reports, were observed in the participants’ science instruction. Writing opportunities tended to focus on shorter activities that included answering questions, recording notes from readings or
investigations, or summarizing information (Drew et al., 2017; Kiuhara et al., 2009). However, the use of modeling included writing that was completed in various forms and in different lengths as recommended by Klein and Ehrhardt (2015). Furthermore, the use of models is consistent with the work of Prain and Hand (2016) and Lent (2015) in integrating writing through collaborative and multi-modal methods. Modeling connected writing to scientific practices and allowed participants to engage students in producing text in a variety of forms to communicate science concepts, ideas, and understanding (Drew et al., 2017; Prain & Hand, 2016). Writing as a component of modeling represented a pedagogical approach to literacy instruction that informed participants PCK (Shulman, 1986, 1987).

One primary use of writing visible in all three participants’ classes was to summarize information (Fisher & Frey, 2008). Melanie used summaries of information read in assigned articles as a means of monitoring student ability to gain information from text and then communicate the understanding. Kaitlyn also used summaries of discussions as an exit ticket in the form of a “two-dollar summary” described earlier to monitor both student learning and misconceptions after engaging in small or large group discourse pertaining to science ideas. In Debra’s Grade 8 instruction, summary writing was used to answer questions based on reading or discussion in class. The use of summaries represented content area literacy instruction that were a prior version of pedagogical knowledge influencing participant PCK (Shulman, 1986, 1987).

While each participant used brief summary writing to respond to activities from class, they also structured opportunities for writing summaries that communicated learning from investigations. Writing conclusions both summarized learning activities and provided information that could be explored further in future investigations or activities. The uses of summaries as writing tasks that are both brief and over longer periods of time are consistent with
recommendations from research but are primarily content area literacy strategies unless focused on communicating information to address a science problem or phenomenon (Klein & Ehrhardt, 2015; Klein & Kirkpatrick, 2010; Klein & Samuels, 2010; Lent, 2015; Piercy & Piercy, 2011). As participants shifted the focus of writing from summarizing for information to communicating information that addressed a science problem or phenomenon, pedagogical knowledge was developed that expanded participant PCK (Shulman, 1986, 1987).

Most writing over an extended period of time occurred through the use of student-generated scientific models as demonstrated by Melanie and Kaitlyn. The use of writing in modeling represented a disciplinary application of writing in science (Klein & Ehrhardt, 2015; Klein & Kirkpatrick, 2010; Klein & Samuels, 2010; Lent, 2015). In the Grades 6 and 7 classes, students obtained information through investigations, reading, and discourse that was then incorporated into a scientific model to describe or address a presented phenomenon. In Melanie’s classes, students were engaged in understanding the function and importance of individual human body systems prior to combining their understanding to explain the functioning of the body. Kaitlyn engaged her students in trying to figure out causes of and solutions to declining barn owl populations by understanding energy flow through ecosystems.

Both Melanie and Kaitlyn structured modeling in small groups that encouraged collaboration and allowed for presentation of information in a variety of ways, including written text, diagrams, and graphic organizers. Additionally, the groups of students returned to the models several times throughout the instructional unit to edit and revise both their thinking and the mechanics of their writing based on feedback from peers and the teacher (Berland & Reiser, 2008; Drew & Thomas, 2018; Prain & Hand, 2016). The use of multiple avenues for communicating information and extended time that utilized feedback to drive revisions aligns
with ideas presented by Prain and Hand (2016) and Lent (2015) for writing as a collaborative and multi-modal process drawing from a variety of source information. The use of writing in modeling also represented new pedagogical knowledge that was applied in the PCK of Melanie and Kaitlyn (Shulman, 1986, 1987).

**RQ4: Speaking and listening implementation in science.** The fourth research question asked what science educators at the urban middle school do in the implementation of science instruction that supports speaking and listening skills. Melanie and Kaitlyn both experienced instructional transitions that resulted from the adoption and implementation of CCSS.

Communication in verbal and visual forms included the practice of speaking and listening skills that, while not explicitly stated in CCSS for science, were included in CCSS English Language Arts standards and infused into district science curricula (Houseal et al., 2016; NGACBP & CCSSO, 2010; Zygouris-Coe, 2012). This allowed Melanie and Kaitlyn to have a degree of familiarity with the need for discussion and practice of speaking and listening. However, the use of these skills in science is expanded as students are expected to engage in argument from evidence, which can include both collaboration and discourse. All three participants noted district training on NGSS that included references to “discourse,” “productive talk,” and “talk moves.”

Mercer (2010) and van der Veen et al. (2015) discussed the importance of student talk in the process of making meaning. All participants utilized learning about discourse in science to structure opportunities for students to engage in collaborative discussions or argumentation from evidence that paralleled processes used by scientists (Yore, 2004). As students became comfortable with the processes of discourse, teachers were able to move from leader of the discussion to guide. This transition of teacher role represented the development of content
knowledge about the practice of discourse by scientists and pedagogical knowledge for facilitating such discussions in middle school science classrooms (Shulman, 1986, 1987, 1998).

The engagement of students in discourse centered on the use of science information in models and in the synthesis of information (Berland & Reiser, 2008; Michaels & O’Connor, 2015; Michaels et al., 2008). Melanie most often engaged students in discourse about ideas represented in and feedback received about models. Kaitlyn engaged students in discourse to synthesize ideas and information gathered from reading and investigations to address a key point related to the barn owl phenomenon. Similarly, Debra used discourse to probe student understanding based on activities, such as in genetics and the uses of Punnett squares as predictive models. Each of these implementations of discourse allow students to use evidence, support positions, and communicate understanding much like experts within the science discipline and were used to drive pedagogical choices for instruction (Fisher & Frey, 2014b; Michaels & O’Connor, 2015; Michaels et al., 2008; Shulman, 1986, 1987).

**RQ5: Science and engineering practices and literacy in science.** The final research sub-question focused on the integration of literacy skills and science and engineering practices in science instruction. The use of a phenomenon, such as Melanie’s questions about how the body allows us to live, Kaitlyn’s presentation of barn owl population data, or Debra’s use of her dog and possible offspring, all three participants planned lessons intended to stimulate student questioning and curiosity as overviewed by Chi (2009). The introduction of a phenomenon to generate questions is consistent with research of Ford (2008) and Klahr and Dunbar (1988) that indicated that questioning allows students to apply prior knowledge. The use of phenomenon represented pedagogical knowledge related to the understanding of students and methods for presenting content in an engaging manner (Shulman, 1986, 1987). When coupled with reading
opportunities as planned by participants, literacy can provide a means of driving questioning and lead to further use of scientific practices, including investigations (Fang & Coatoam, 2013; Rupley, 2010; Yager, 2004).

As discussed previously, the use of scientific modeling, especially by Melanie and Kaitlyn, provided opportunities for students to engage in both writing and collaboration that includes speaking and listening skills. As presented by Berland and Reiser (2008) and Schwarz et al. (2009), modeling allows for review of content and processes, feedback from peers and the teacher, and revisions by students. Melanie and Kaitlyn structured lessons that allowed students to engage in these processes to construct knowledge and share ideas, thus incorporating literacy throughout the process of modeling. The structuring of lessons represented the application of PCK to present science content knowledge through the pedagogy focused on writing and collaboration (Shulman, 1986, 1987).

Literacy used to stimulate student interest as suggested by Enfield (2014) and McClune et al. (2012) can lead to investigations. Discourse and reading were used by all three participants to produce claims that were then investigated to generate evidence and reasoning for the outcomes (Berland & Reiser, 2008; Klahr & Dunbar, 1988). Investigations produce data that must be analyzed and was presented in different forms that include qualitative descriptions of joint types in Melanie’s classes and quantitative data of the number and type of animals consumed by barn owls in Kaitlyn’s classes. Debra structured the use of Punnett squares to provide a combination of quantitative data in the form of percent chance for resulting qualitative descriptions of offspring. Opportunities for students to use data to construct knowledge were structured by all three participants and represented the process of science described by Yager (2004).
The processes of science included reading to interpret data sets and graphs, writing to communicate information in models, and communicating through verbal means that include speaking and listening skills (Berland & Reiser, 2008; Ford, 2008; Schwarz et al., 2009; Yore, 2004). Communication of understanding through opportunities for discourse and in writing were included by participants. Communication allowed students to construct knowledge and explain this knowledge in a variety of forms, including the written and verbal practices of supporting an argument with evidence (Berland & Reiser, 2008; Ford, 2008; Schwarz et al., 2009; Yore, 2004).

Integration of literacy and science and engineering practices as disciplinary literacy.

The use of reading, writing, speaking and listening, and science and engineering practices have been reported as separate categories of literacy and science instruction consistent with the research sub-questions. When learned and used independent of content, reading, writing, and speaking and listening skills represent content area literacy learning as it is generalized and devoid of disciplinary application (Fisher & Ivey, 2005; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). However, these categories can overlap through the course of instruction in the science classroom as demonstrated by participants in this study. When literacy skills are applied to science practices, disciplinary literacy emerges as a means for constructing science knowledge (Norris & Phillips, 2003). This overlap of literacy skills and science and engineering practices was exhibited in the instruction planned and implemented by each participant and represents the development of PCK specific to disciplinary literacy and science instruction (Shulman, 1986, 1987). Disciplinary literacy PCK of participants can situate literacy as tools that provide opportunities for students to construct science knowledge through practices (Faggella-Luby et al., 2012; Houseal et al., 2016).
Kaitlyn and Melanie introduced the development, revision, and sharing of models as a means for constructing science knowledge. Scientific modeling required students to obtain information and then communicate understanding of the science concepts, thus engaging in science practices identified in NGSS (NGSS Lead States, 2013). Reading and listening skills provided the means for obtaining information through research and discourse, thus representing the input of science information through literacy that included reading with the purpose of learning about a driving question, investigating ideas related to the driving question, analyzing data, and discussing ideas (Houseal et al., 2016; Norris & Phillips, 2003). Opportunities to apply this information in constructing models related to the science concepts represented in the anchoring phenomena (Schwarz et al., 2009). After creating the model, students were then expected to explain the model either through writing or through speaking, representing outputs of constructed science knowledge through written and oral literacy components (Drew & Thomas, 2018; Houseal et al., 2016; Norris & Phillips, 2003). Examples of modeling barn owl populations and human body systems in the classrooms of Kaitlyn and Melanie represent the development and use of PCK (Shulman, 1986, 1987). Literacy as applied in disciplinary literacy learning in the development and communication of a scientific model is summarized in Figure 5.

![Disciplinary Literacy Use in the Development and Communication of Scientific Models](image)

*Figure 5. Disciplinary literacy use in the development and communication of scientific models.*
Participants also used investigations to develop science knowledge and incorporate disciplinary literacy, thus reflecting the development of disciplinary literacy PCK through investigations (Shulman, 1986, 1987). Disciplinary literacy resulting in questioning, the need to gather and evaluate information, and make predictions represented inputs of information that informed investigations (Houseal et al., 2016; Norris & Phillips, 2003; Yager, 2004). Investigations required reading to understand the steps required to complete an activity as in the case of building a robotic hand in Melanie's class or to determine simulated offspring in Debra's class. Kaitlyn used reading as a tool for identifying bones discovered during an owl pellet dissection. In addition to reading, investigations were structured to allow students opportunities for engaging in speaking and listening skills to support obtaining evidence to address lesson-level and anchoring phenomena (Houseal et al., 2016; NGSS Lead States, 2013; NRC, 2012).

After gathering data or evidence, participants structured follow-up activities that included answering questions, application of findings to current models, and direct instruction for creating graphs to analyze data that is incorporated into explanations of science content, thus representing opportunities for students to present knowledge through outputs that required the use of disciplinary literacy (Drew & Thomas, 2018; Goldman et al., 2016; Houseal et al., 2016; Norris & Phillips, 2003). The use of investigations shown in Figure 6 represents opportunities for applying literacy skills in ways consistent with disciplinary literacy and the intent of Moje (2008) and Shanahan and Shanahan (2008).

Argumentation from evidence is a process that uses literacy to construct understanding of science concepts and then communicate this understanding (Berland & Reiser, 2008). As discussed previously, the use of models as facilitated by Kaitlyn and Melanie allowed students to construct understanding and arguments. As with scientific modeling, the development and
communication of arguments relies on the use of literacy skills similar to that of modeling. Furthermore, evidence can be gathered through investigations, which also require the use of literacy skills. The implementation of learning opportunities for the development of argumentation skills demonstrated an understanding of the content of argumentation in science and the methods for implementing argumentative discourse in science instruction (Berland & Reiser, 2008; Michaels & O’Connor, 2015; Shulman, 1986, 1987).

![Disciplinary Literacy Use in Scientific Investigations](image)

**Figure 6.** Disciplinary literacy use in scientific investigations.

The presentation of an anchoring phenomenon or lesson-level phenomenon provided by Kaitlyn and Melanie structured opportunities for students to engage in the science practice of questioning. To aid in development of questions, Kaitlyn and Melanie used reading and discussion to provide background information. Kaitlyn selected articles for students to read and then discuss as table groups and as a whole class. The presentation of articles contained written information and diagrams from which students could draw information used in questioning. Melanie used a combination of teacher-provided articles from science magazines and student-directed research to obtain information that resulted in questions that required further learning (Houseal et al., 2016; NGSS Lead States, 2013). The use of articles to elicit questions and address phenomena represented a change in pedagogical knowledge (Shulman, 1986, 1987).
As participants planned for and implemented literacy skill and science and engineering practice instruction, disciplinary literacy was visible in the overlap of skills and practices. Participant actions structured literacy uses authentic to the science discipline, which parallel the uses of literacy by scientists. Each participant identified literacy instruction as an important in planning and therefore an intentional component of instruction. As participant PCK evolved to include instruction that integrated science and engineering practices, use of literacy transitioned to increasingly disciplinary-focused applications (Faggella-Luby et al., 2012; Goldman et al., 2016; Houseal et al., 2016; NGSS Lead States, 2013; Norris & Phillips, 2003; Shulman, 1986, 1987).

**Chapter Summary**

The study explored the use of disciplinary literacy in three middle school classrooms. Participants’ understanding of disciplinary literacy and the use of reading, writing, speaking and listening, and science and engineering practices were explored through observations, interviews, and document reviews. Results of within case analyses for three cases were reported prior to cross-case analysis of the three cases. All three participants demonstrated use of disciplinary literacy instruction in their science classrooms through authentic uses of reading, writing, and speaking and listening. Participants also attributed changes in instruction due to state and district decisions to adopt NGSS also impacted disciplinary literacy instruction as science and engineering practices became an important component of instruction.

Melanie and Kaitlyn benefited directly and indirectly from a professional development offered through a local university. Classroom practices were being adapted in response to learning that took place in the professional development as experienced by Melanie and shared with Kaitlyn by a grade level colleague. Literacy use moved from content area literacy
instruction to application consistent with uses in the discipline of science. This movement resulted as students developed agency related to science and engineering practices that required a use of literacy that allowed students to access and apply information gathered from multiple sources.

Debra was a novice teacher in her second year of teaching. She identified a lack of training in literacy as an impediment to implementation of disciplinary literacy. Due to a lack of formal training on literacy instruction in science, she drew on personal experiences as a student to inform her pedagogy. Debra’s experiences coupled with district-provided training on the structure of NGSS resulted in instruction that built on the use of reading and inquiry to include disciplinary literacy practices. Melanie reported a similar deficit in pedagogy for literacy when beginning her teaching career, but she engaged in in-service development opportunities that allowed her to develop knowledge of literacy and pedagogy to implement instruction within her science classroom. Like Melanie, Debra was willing to engage in development opportunities to improve her literacy and NGSS science PCK.

All three participants identified reading, writing, and speaking and listening skills as important components of science instruction. Participants also identified text as more than traditional written word presented as textbooks and articles. Diagrams, tables, charts, graphs, and data sets were viewed by all participants as varieties of text used in the science discipline. Participants regarded reading as the process of obtaining and interpreting information. Writing was the process of expressing information and understanding in written forms. However, these written forms were not limited to words and could include models, charts, graphs, and diagrams with or without labels. Literacy in science included the communication of ideas, which participants linked to discourse that included skills for speaking and listening. Science and
engineering practices presented in NGSS were viewed by all participants as positive supports for the meaningful integration of literacy in science instruction.

Participants shared common successes through the implementation of learning opportunities that integrated disciplinary literacy and science content instruction. The use of disciplinary literacy furthered participants’ understanding of NGSS instruction and the incorporation of the three-dimensions of science instruction outlined in NGSS. The successes were not without obstacles. Participants developed planning that was flexible and could respond to student needs through the adjustment of time devoted to activities. Planning also needed to account for student agency or lack of agency in relation to the skills and practices being utilized in science teaching and learning and the development of learning environments that fostered use of disciplinary literacy skills and science and engineering practices. Participants also faced limitations in the form of a lack of training and a lack of opportunities for practicing pedagogy learned through workshops and development sessions. Overall, participant use of disciplinary literacy in science content instruction facilitated student learning through implementation of NGSS despite obstacles and limitations. Through addressing obstacles and furthering training opportunities, disciplinary literacy instruction in science could be strengthened.

The final chapter will present an overview of the entire study by summarizing the research study and major findings. Conclusions will be presented prior to the interpretations of findings. The implications of the research for additions to the knowledge of scholarly literature, impacts on teacher practice, and policy and decision-making will be presented. Suggestions for future research will be outlined along with limitations and reflexivity.
Chapter 5: Summary, Conclusions, Implications, and Suggestions for Future Research

This study was an exploratory investigation of the implementation of disciplinary literacy instruction in middle school science classrooms. The study focused on the question, "How do science educators in an urban middle school implement disciplinary literacy instruction in the science classroom?" This question was supported by five sub-questions. The first sub-question explored science teacher knowledge, training, and experience related to disciplinary literacy. The following three sub-questions focused on components of disciplinary literacy, including reading, writing, and speaking and listening skills. The final sub-question explored the integration of literacy skills with science and engineering practices. Three teachers representing different grade levels and experience participated in the study, representing three cases in a multiple case study qualitative research approach. The study included observations, interviews, and document reviews focused on methods for and obstacles to disciplinary literacy instruction in middle school science classes.

The implementation of disciplinary literacy instruction in Grades 6-8 science classes was explored in this study and contributes to the understanding of middle school science teacher PCK for disciplinary literacy. The study provides evidence of successes and challenges of disciplinary literacy instruction and provides a basis for further investigations of disciplinary literacy in science classes. Data were collected and analyzed to identify themes about teachers’ understanding and implementation of disciplinary literacy instruction. A summary of methods, results, and major findings will provide an overview of the study. After presenting the summary and major findings, conclusions supported by the literature and data will be discussed, followed by interpretations of findings of the study. Implications of the study, including contributions to the field, impacts on policy and decision-making, and improvements to professional practice will
be presented. Suggestions for future research were outlined and related to the study of disciplinary literacy. Context and constraints of the study will be presented as limitations and reflexivity followed by a summary of the chapter.

**Summary and Major Findings**

Instruction in science has been impacted by changes in standards, such as through the adoption of CCSS, NGSS, or other state and local standards (Hannant & Jetnikoff, 2015; NGACBP & CCSSO, 2010; NGSS Lead States, 2013). These changes in standards have resulted in evolving support for the teaching of literacy within the science discipline. Approaches to literacy instruction in science have re-emphasized the need to utilize literacy as relevant to the science discipline. This re-emphasis is consistent with the recommendations by Shanahan and Shanahan (2008, 2015), Moje (2008, 2015), and Fisher and Ivey (2005) to embed literacy instruction in ways that are used by experts in the discipline and is termed disciplinary literacy.

While standards and research support such instructional approaches, disciplinary literacy primarily remains a conceptual form of instruction within the literature (Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015; Zygouris-Coe, 2012).

To improve literacy instruction in the science discipline, Fang and Coatoam (2013) called for research that explores the transfer of conceptual understandings of disciplinary literacy to practice that re-emphasizes applications of literacy within the discipline, including changes to instruction inclusive of science and engineering practices. The purpose of this qualitative case study was to explore the disciplinary literacy instruction implemented in middle level science classrooms in an urban middle school in the United States. To address the need expressed by Fang and Coatoam (2013), this study narrowed to focus on the implementation of disciplinary literacy by in-service educators in middle level science classrooms by addressing the following
overarching question: What do science educators in an urban middle school know about and do to implement disciplinary literacy instruction in the science classroom? The research question was supported by five sub-questions:

**RQ1:** What are the prior disciplinary literacy knowledge, training, and development experiences of science educators?

**RQ2:** What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of reading skills?

**RQ3:** What do participating science educators at the urban middle school do in the implementation of science instruction to support the learning and use of writing skills?

**RQ4:** What do participating science educators at the urban middle school do in the implementation of science instruction to support speaking and listening skills?

**RQ5:** What do participating science educators at the urban middle school do in the implementation of science instruction to integrate literacy skills and science and engineering practices?

The research study focused on educator actions that included planning, implementation, assessment, and reflection on instruction. Shulman’s (1986, 1987) theory of PCK provided a framework for understanding the interactions of pedagogical and content knowledge resulting in an understanding of disciplinary literacy and the actions of teachers to implement disciplinary literacy instruction. This study described and analyzed educator actions using qualitative case study methods. The analyses and results of the study contribute to addressing existing gaps in the literature by exploring implementation of disciplinary literacy in science teacher planning, implementation, and reflection on instruction as suggested by Fang and Coatoam (2013).
A re-emphasis of literacy instruction that is implemented with respect to authentic uses in the disciplines is supported in standards for teaching science (Faulkner, 2012; Hannant & Jetnikoff, 2015; MacMahon, 2014; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Tang, 2016). Disciplinary literacy instruction can be structured to teach literacy skills in ways relevant to literacy as used by experts in the discipline as proposed by Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015). To meet the expectations of increased literacy instruction that is meaningful to students in disciplines, there is a need for educators to understand disciplinary content and pedagogy and literacy content and pedagogy. As the study considered the PCK of educators, educator understanding of literacy content and pedagogy within the content and pedagogy of science was explored as it led to the implementation of disciplinary literacy instruction in science to provide both literacy and content learning opportunities for students (Norris & Phillips, 2003; Shulman, 1987). As participants in the study prepared for teaching new science standards, the incorporation of science and engineering practices allowed for activities that paralleled the use of literacy by expert scientists and integrated reading, writing, and speaking and listening in ways consistent with disciplinary uses (NGACBP & CCSSO, 2010; NGSS Lead States, 2013). The application of Shulman’s (1986, 1987) theory of PCK provided a framework for the exploration of teaching of literacy in science classrooms that included science and literacy content and pedagogy necessary in educator practice.

The purpose of the study was to explore the disciplinary literacy instruction implemented in middle level science classrooms to address the problem of improving literacy achievement through changes in literacy instruction. Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015) proposed disciplinary literacy to address the need for changing instruction in subject-specific courses. The exploration of science teacher actions in the implementation of disciplinary
literacy instruction was completed using the qualitative research paradigm. The use of the qualitative paradigm allowed for understanding the perceptions and actions of teachers in planning and implementing disciplinary literacy research in middle level science classrooms (Bogdan & Biklen, 2007). The use of qualitative case study methods as described by Stake (1995) and Yin (2014) were used to explore disciplinary literacy implementation by three middle school science teachers.

The exploration of science and literacy content and pedagogy was guided by a case study qualitative research design presented by Stake (1995) and Yin (2014) to determine the perceptions, understandings, and implementation of disciplinary literacy PCK of science educators teaching science courses in an urban, middle level school in the United States. Three participants represented three cases in a multiple case study. Data were collected on each case through observations, semi-structured interviews, and document reviews using a relativist, emic approach. Codes derived from the literature on literacy and science instruction were used to create pre-determined codes for the initial phase of coding. Additional cycles of coding were used to generate themes from each case that were analyzed within each case and then synthesized through cross-case comparisons and contrasts focused on disciplinary literacy PCK and implementation in science instruction (Saldaña, 2016; Stake, 1995; Yin, 2014). Prior to the study, permission was obtained from the school district and from the selected site. Informed consent from participants and approval from IRB were obtained prior to the study. Confidentiality was protected throughout the duration of the study and reporting of findings as data were kept confidential and anonymous with all identifiers removed prior to reporting. Researcher decisions were based on ethics that allow the interpretation of data with minimal impacts of researcher bias (Stake, 1995). Member checking and triangulation represented the
steps taken within the study to ensure the impartiality of data collection (Bogdan & Biklen, 2007; Yin, 2014).

The site selected for the study was accessible to the researcher as recommended by Stake (1995) and contained cases that aligned the research goals (Yin, 2014). The site was chosen as it was also a typical example of a middle school structure in the United States that could enhance the transferability of interpretations and conclusions of the study (Stake, 1995). Eight teachers at the site that maintained certification for teaching middle school science and were assigned teaching roles in science classes were recruited to participate in the study. Three teachers representing three cases and spanning science instruction in Grades 6-8 agreed to be participants in the study. All three participants identified as female and were full-time science teachers in the selected site. The experience of these participants varied with the Grade 6 teacher having 20 years of teaching experience with 13 of these years focused on Grade 6 science. The Grade 7 teacher had 11 years of science teaching experience that spanned Grades 7 and 8. The Grade 8 teacher was completing her second year of teaching experience, both in Grade 8 science at the site. The selection of the site and recruitment of participants aligned with the research goals and expectations of studying the implementation of disciplinary literacy in science classrooms allowing for data collection and analysis.

Data were collected through observations, interviews, and document reviews over a nine-week period that spanned one instructional unit for each participant. Data for each participant were recorded through the use of observation and document review protocols. Interviews were recorded and transcribed verbatim. Analysis of case study data considered the research question and sub-questions. The analysis progressed from the sub-questions, representing questions of smaller scope, to the overall, larger-scope research question as recommended by Yin (2014).
Data was coded by the researcher to represent key ideas and themes generated by initial analysis of data using predetermined codes based on literature and refined through subsequent iterations of coding (Saldaña, 2016). The theory of PCK was applied to support analysis within each case and between cases through cross-case synthesis of data from observations, interviews, and document review of data from the three cases (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1987; Yin, 2014). Themes encompassing the major findings resulting from data analysis were organized and reported as aligned with the research sub-questions with respect to teacher experience, reading, writing, speaking and listening, and science and engineering practices.

First, background experiences for all three participants were rooted in practices consistent with content area literacy instruction. These experiences informed participants’ decisions regarding literacy instruction but were changing as new professional learning opportunities and new standards for instruction were incorporated into developing PCK for disciplinary literacy instruction in science (Daehler et al., 2015; Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008; Shulman, 1986, 1987). Moving from developing PCK based on experience, participants viewed text as inclusive of written word, diagrams, tables, charts, graphs, and data sets that required interpretation for gaining information (Anders & Guzzetti, 2005; Anderson, 1999; Norris & Phillips, 2003; Vellom & Anderson, 1999). Using this broad definition of text, participants implemented reading instruction consistent with uses in science as a component of engaging in science practices (Lemke, 2004; Norris & Phillips, 2003; Yore, 2004). Additionally, writing was structured in science lessons for the purposes of communicating understanding and developing knowledge about science. Summaries were used as short-term writing with the intent of demonstrating understanding (Drew et al., 2017; Prain & Hand, 2016). Scientific models
created by students also utilized writing over long periods of time that included opportunities for feedback and revision (Lent, 2015; Prain & Hand, 2016). Drawing on recommendations in CCSS (NGACBP & CCSSO, 2010) and the research of Michaels and O’Connor (2015), participants included opportunities for speaking and listening that included discourse to express knowledge and to replicate the processes of scientists who utilize talk to make meaning and form group consensus (Mercer, 2010; van der Veen et al., 2015; Yore, 2004). Finally, science and engineering practices provided a context for teacher planning and implementation of lessons that integrated disciplinary literacy instruction that aligned science standards with authentic literacy instruction (Goldman et al., 2016; Houseal et al., 2016).

Conclusions

Data were collected in Grades 6-8 science classrooms and were initially coded using a set of pre-determined codes based on literature. Conclusions were developed as themes emerged from multiple cycles of coding data within cases and during cross-case analysis. Conclusions will be presented in this section as aligned with the research sub-questions. Participant experience with disciplinary literacy instruction will be presented followed by conclusions on reading, writing, speaking and listening, and science and engineering practices.

**Experience with disciplinary literacy.** Participant experience with disciplinary literacy varied based on prior teaching experience and opportunities for engaging in professional learning. Two participants were veteran teachers with 11 years and 13 years of science teaching experience. The third participant was a beginning teacher in her second year of teaching. In addition to teaching experience, one participant was engaged in a multiple year professional development experience focused on NGSS and inclusive of disciplinary literacy. These factors influenced participant approaches to literacy instruction in science.
Shulman (1986, 1987) proposed that experience and learning opportunities can impact the development of PCK. When considering PCK, decision-making can be influenced by what is known and what has been experienced by teachers. In this study, literacy training of all three participants had primarily focused on content area literacy approaches. Implementation of aspects of various professional learning, both preservice and in-service, created experiences that drove instructional choices. Therefore, content area literacy instruction was the default method that informed choices and decision-making for planning and during implementation. To enhance PCK for disciplinary literacy in science, new experiences and learning opportunities needed to be present (Daehler et al., 2015; Park et al., 2011; Shulman, 1986, 1987).

Consistent with the research of Daehler et al. (2015), Park et al. (2011), and Stasinakis and Athanasiou (2016), teachers who engaged in professional development and implemented learning from the professional development can build classroom instructional experiences that aid in the evolution of PCK. One participant engaged with a professional learning opportunity that provided information and planning experience related to both NGSS and disciplinary literacy. She credited this professional development with increasing her awareness of and ability to integrate literacy in meaningful ways within science instruction. As science instruction included the use of science practices, disciplinary literacy instruction aided in classroom experiences where literacy use led to content learning and application (Norris & Phillips, 2003; Goldman et al., 2016; Shanahan & Shanahan, 2008, 2015). Professional development can provide opportunities for developing PCK, including PCK for science and disciplinary literacy instruction (Daehler et al., 2015; Shulman, 1986, 1987).

**Reading.** All three participants viewed reading as valuable to science learning. Uses of reading by participants ranged from reading directions to interpreting data presented in charts
and graphs. Participants viewed text in science as inclusive of written word, diagrams, charts, graphs, and data sets that were sources of information and required interaction with and interpretation of material to develop conclusions (Anders & Guzzetti, 2005; Anderson, 1999; Lemke, 2004; Norris & Phillips, 2003; Vellom & Anderson, 1999). The definition of text as more than written word allowed participants to incorporate reading in diverse ways that both stimulated student interest as suggested by Enfield (2014) and McClune et al. (2012) and served as a component of practicing science as demonstrated by expert scientists (Lemke, 2004; Norris & Phillips, 2003; Shanahan & Shanahan, 2008, 2015; Yore, 2004).

As Yager (2004) offered, reading was viewed by participants as more than decoding words and being able to comprehend and remember text. This view led to the use of literacy in science practices of analyzing and interpreting information. As science practices occur through planning and implementation that lead to explorations, science practices can be driven by disciplinary literacy (Anders & Guzzetti, 2005; Fang & Coatoam, 2013; Piercy & Piercy, 2011; Rupley, 2010; Shanahan & Shanahan, 2008, 2015; Yager, 2004; Yore, 2004). Specifically, reading can become a process of analyzing, interpreting, and inferencing to develop and synthesize information necessary for building science content knowledge (Clinton & van den Broek, 2012; Linderholm et al., 2014; Piercy & Piercy, 2011; Yager, 2004; Yore, 2004). Participants’ integrated use of disciplinary literacy as fundamental processes for engaging in science practices and building content knowledge is consistent with the work of Goldman et al. (2016) and Norris and Phillips (2003).

Reading as defined by participants and supported by research included processes of analysis, interpretation, and making inferences from various forms of text (Anders & Guzzetti, 2005; Anderson, 1999; Norris & Phillips, 2003; Vellom & Anderson, 1999). The use of reading
skills in science is important as outlined by Norris and Phillips (2003) in allowing students to access derived science knowledge. Through the integration of data and information in graphs, charts, diagrams, and written word as texts, reading was present in lesson planning and implementation as it was applied in science practices. Participants stated that reading was an integral process in interpreting information that could lead to student understanding of concepts. The relevancy of reading to answer scientific questions or address phenomena fits with the uses of disciplinary literacy instruction that parallels literacy uses by expert scientists (Moje, 2008, 2015; NGSS Lead States, 2013; Shanahan & Shanahan, 2008, 2015).

Based on participants’ identification of reading as interpreting information, the application of reading in disciplinary contexts was supported through the science and engineering practices outlined in the NGSS, specifically developing questions and obtaining, evaluating, and communicating information (NGSS Lead States, 2013). When presenting a scientific phenomenon or problem, participants were initiating opportunities for student interpretation requiring the evaluation of information leading to the development of questions (Chi, 2009; Ford, 2008; Klahr & Dunbar, 1988). The literacy skills of reading and interpretation are embedded within the use of science and engineering practices of obtaining and evaluating information and formulating questions (Fisher & Ivey, 2005; Houseal et al., 2016; NGSS Lead States, 2013). Combining science and literacy skills results in a disciplinary literacy approach consistent with the recommendations of Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015). When the skills of gathering and interpreting information and questioning are integrated and not taught separately, they are relevant to students and the disciplinary content being studied (Klahr & Dunbar, 1988; Shanahan & Shanahan, 2008, 2015).
Investigations and analyses of data, both science and engineering practices, were also used by participants to incorporate opportunities for applying reading skills within the discipline (Houseal et al., 2016; NGSS Lead States, 2013). Investigations grew from questioning as a means for procuring information and evidence that answers questions, aids in the development of solutions to a problem, and lead to chances for synthesizing information (Anders & Guzzetti, 2005; Berland & Reiser, 2008; Ford, 2008; Yore, 2004). Lessons were structured to include investigation through activities such as guided experiments or student-developed inquiry activities. Students were required to apply reading skills to follow procedures for these investigations or activities. Recorded evidence and student reasoning about observations from inquiry investigations were used by participants to create opportunities for the analysis and interpretation of data (Houseal et al., 2016; NGSS Lead States, 2013).

Finally, the science and engineering practice of obtaining and evaluating information was used to facilitate disciplinary uses of reading (NGSS Lead States, 2013). While reading for research may be viewed as a content area literacy skill, the application in conjunction with a driving question or phenomenon represents a disciplinary use of reading (Houseal et al., 2016; Norris & Phillips, 2003). Participants organized lessons that required students to engage in research using digital or print resources as sources of information and focused on reading to gain information about the phenomenon or driving questions. For example, in Kaitlyn’s unit on declining barn owl populations and impacts on ecosystems, one reading required students to gain information on the role of the barn owl within the ecosystem. This use of reading resulted in gathering and evaluating information to address the phenomenon of the impacts of fewer barn owls (NGSS Lead States, 2013). Reading to obtain information and the evaluation of this information through interpretation represents disciplinary uses of reading supported through the

**Writing.** In addition to reading, writing was viewed as an important form of literacy in science instruction. Participants expressed value in writing to summarize and communicate ideas based on the analysis and interpretation of information from reading diverse forms of text and engaging in investigations. Consistent with research presented by Prain and Hand (2016), writing was not limited to an individual endeavor. Collaborative and multi-modal experiences included the generation of written text as well as models with diagrams, labels, and representations of data (Lent, 2015; Prain & Hand, 2016). These experiences also represented writing opportunities of varied forms and lengths with the purposes of communicating a current understanding or explaining a phenomenon or science idea (Drew et al., 2017; Klein & Ehrhardt, 2015; Klein & Kirkpatrick, 2010; Klein & Samuels, 2010).

Writing as a component of disciplinary literacy instruction in science was implemented by participants in two primary ways. First, participants planned summary writing as a means of communicating small segments of learning based on reading, an investigation, a mini-lecture, or another type of presentation of information. Summary writing is typically a content area literacy strategy but can be utilized in disciplinary literacy instruction when applied to a driving question or in the summary or conclusion of an investigation that addresses a driving question or solves a problem. For example, the unit implemented in Melanie’s classroom focused on the importance and interactions of various human body systems through the phenomenon of a functioning body made up of many different systems. Writing required the processing of text and investigations to address both individual systems and the interactions of these systems culminating in a student-created scientific model that incorporated summaries of systems within the context of the entire
human body. These pieces of writing were often short, were not edited or revised throughout multiple iterations, and were typically in response to a question or prompt based on the learning activity (Klein & Ehrhardt, 2015; Klein & Kirkpatrick, 2010; Klein & Samuels, 2010; Lent, 2015; Piercy & Piercy, 2011). The intent of these writing activities was to produce a brief text that demonstrated or communicated science ideas or understanding about a phenomenon and related driving question (Drew et al., 2017; Prain & Hand, 2016).

The second common implementation of writing included the use of scientific modeling to communicate ideas. The use of scientific modeling served as a collaborative effort to produce various forms of text (Lent, 2015; Prain & Hand, 2016). Writing in scientific modeling involved the expression of ideas synthesized from various sources and presented as written text supported by diagrams and data expressed as charts and graphs (Lent, 2015; Norris & Phillips, 2003; Prain & Hand, 2016). The creation of models was both collaborative as students produced them in small groups and iterative with cycles of revision as students discovered new information. The revisions of models incorporated long-term writing sequences as students integrated new learning and responded to both peer and teacher feedback (Klein & Ehrhardt, 2015; Klein & Kirkpatrick, 2010; Klein & Samuels, 2010; Prain & Hand, 2016).

Science and engineering practices also support the use of writing in a discipline-specific context. The practices of creating investigations, communicating information, and developing scientific models are areas that may include the use of writing (NGSS Lead States, 2013; Shanahan & Shanahan, 2008, 2015). Participants structured opportunities for students to develop and write procedures for investigations. When participants planned and implemented research activities, students were responsible for communicating the information discovered in the research. The use of scientific models provided opportunities for students to engage in short-term
writing within the model to label or explain diagrams and illustrations. Chances for long-term writing assignments consistent with disciplinary uses were also provided by participants within scientific modeling as students were able to revise and expand the written components of their models as new information was gathered and new knowledge was constructed. Science and engineering practices allowed participants to embed writing activities within science instruction through investigations, research, and modeling (Drew et al., 2017; Houseal et al., 2016; Moje, 2008, 2015; NGSS Lead States, 2013; Shanahan & Shanahan, 2008, 2015).

Opportunities for disciplinary uses of writing included both short-term and long-term writing assignments. Participants structured lessons based on questions or prompts to promote short-term written summaries to communicate understanding in relation to a phenomenon or driving question (Drew et al., 2017; Prain & Hand, 2016). They also provided long-term writing instruction and application in varied forms through the generation of scientific models. The primary uses of focused summaries and scientific modeling allowed participants to integrate writing as relevant to science practices (Goldman et al., 2016).

**Speaking and listening.** Speaking and listening skills are included as literacy skills in CCSS (NGACBP & CCSSO, 2010) and fit in participants’ views of literacy as applied through science. Participants referenced the use of speaking and listening when planning small and large group discourse, particularly in the use of methods outlined by Michaels and O’Connor (2015). By engaging students in discourse, speaking and listening were not only a means of sharing information but also a process of making meaning from information (Mercer, 2010; van der Veen et al., 2015). Using talk to make meaning include the planning and implementation of oral or verbal tasks within scientific modeling and investigations to engage students in the processes
and practices used by scientists (Mercer, 2010; van der Veen et al., 2015; Yore, 2004). Two methods for using speaking and listening included scientific modeling and class discussions.

The integration of discourse and scientific modeling provided various opportunities to practice speaking and listening skills. Through the science practice of modeling, participants created activities that included collaboration to construct and then communicate understanding of science related to a phenomenon or driving question (NGSS Lead States, 2013). Scientific models were presented by students for peer and teacher feedback and to demonstrate learning constructed by students. By providing opportunities to argue from evidence allowed for experiences that used evidence in defense of ideas that paralleled literacy used by expert scientists (Fisher & Frey, 2014b; Michaels & O’Connor, 2015; Michaels et al., 1992; Michaels et al., 2008; van der Veen et al., 2015; Yore, 2004).

Whole class discussions also required the use of speaking and listening skills in response to a prompt or multiple questions posed by the teacher or students. Students would share ideas and be encouraged by the study participants to share more about students’ own ideas or to build on ideas presented by peers. Participants furthered these discussions using questions or statements consistent with the recommendations of Michaels and O’Connor (2015) and presented as part of district training in NGSS. Depending on the intent of discussions, students would be asked to revise prior thinking about a prompt or to come to a class consensus that explained a phenomenon or answered a question (Mercer, 2010; Michaels & O’Connor, 2015; van der Veen et al., 2015; Yore, 2004).

Visual and verbal forms of communication relying on speaking and listening skills represented valuable methods for constructing knowledge of science (Houseal et al., 2016; Zygouris-Coe, 2012). Participants used collaboration on and presentation of models along with
whole class discussions to foster opportunities for speaking and listening as components of disciplinary literacy instruction. The verbal tasks planned by participants prompted learning and use of practices used by scientists throughout investigations and processes of sensemaking in science (Mercer, 2010; van der Veen et al., 2015).

**Science and Engineering Practices.** During the period of the study, participants were transitioning instructional strategies to align with three-dimensional instruction in NGSS (NGSS Lead States, 2013). Science practices included in NGSS can incorporate disciplinary literacy instruction to meet the needs of students in both science and literacy (Houseal et al., 2016; Zygoris-Coe, 2012). As participants planned for lessons, they included science and engineering practices outlined in NGSS in ways that authentically integrated disciplinary literacy as used by scientists. As described in the previous sections on reading, writing, and speaking and listening skills, integration of literacy was planned through opportunities for questioning, gathering and communicating information through investigations and text, scientific modeling, interpreting, explaining, and arguing from evidence (NGSS Lead States, 2013).

Participants used science practices to build opportunities for disciplinary literacy instruction. Throughout science processes, participants facilitated lessons that built on and strengthened skills for literacy as relevant to broader applications by science experts. Participants planned for the use of critical thinking and analysis in conjunction with science practices. The use of literacy skills relied on science practices in instruction (Goldman et al., 2016; Houseal et al., 2016). Participants structured lessons that utilized science practices leading to disciplinary literacy skill development (Goldman et al., 2016; Houseal et al., 2016; NGACBP & CCSSO, 2010; NGSS Lead States, 2013; Norris & Phillips, 2003; Shanahan & Shanahan, 2008, 2015).
**New learning from the study.** While I initially viewed literacy instruction as either a separate content knowledge to be taught in science or as an integral component in the content knowledge of science, I developed an understanding of the implementation of literacy instruction that does not need to be focused on solely content area or disciplinary instruction (Brozo et al., 2013; Faggella-Luby et al., 2012; Fisher & Ivey, 2005). My developing understanding was consistent with Brozo et al. (2013) and Faggella-Luby et al. (2012) who recommended a balance between content area and disciplinary literacy approaches. I also learned that the attitudes and views of educators may impact the success of literacy instruction and the range of application in both content area and disciplinary approaches (Fisher & Ivey, 2005). When participants considered pedagogy aligned with the dimensions of instruction presented in the NGSS, I saw that literacy became embedded in their planning and more closely paralleled the view of literacy as an integral component of science instruction (Fisher & Ivey, 2005; NGSS Lead States, 2013; NRC, 2012). As I observed the participants and analyzed data, I came to understand that an increase in learning about the NGSS and related instruction resulted in literacy instruction that aligned with disciplinary uses within science. However, I ascertained that participants’ implementation of some content area instruction was still necessary to meet the needs of students and goals of instruction.

One key point in my learning was that instructional transitions to the NGSS aided in developing pedagogy that used literacy in authentic ways. Thus, professional development experiences focused on science instruction can simultaneously provide avenues for developing disciplinary literacy instructional strategies (Bennett & Hart, 2014; Buczynski & Hansen, 2010; NGSS Lead States, 2013; NRC, 2012; Roseler & Dentzau, 2013; Zhang et al., 2015). When studying planning for teaching science and engineering practices such as obtaining, evaluating,
and communicating information, I discovered that participants relied on literacy practices applied to uses in science. The application of practices focused on reading to gather information relevant to an observed or experienced phenomenon, constructing and communicating knowledge about the phenomenon through writing and discourse (Berland & Reiser, 2008; Drew & Thomas, 2018; Houseal et al., 2016; Yager, 2004). Furthermore, I recognized that participants did not have to experience professional development experiences first-hand but could gain valuable perspectives from collaboration. The professional development experiences and collaboration with colleagues provided opportunities for developing PCK that impacted approaches to literacy instruction through the incorporation of science and engineering practices (Houseal et al., 2016; NGSS Lead States, 2013).

The simultaneous development of science and disciplinary literacy pedagogy illustrated for me the importance of professional development experiences (Bennett & Hart, 2014; Buczynski & Hansen, 2010; Roseler & Dentzau, 2013; Zhang et al., 2015). The professional development experiences do not need to maintain a sole focus on disciplinary literacy but may encompass a holistic approach for science education. When considering the dimensions instruction outlined by the NGSS, I discovered that teachers can also develop a means for incorporating uses of literacy that are authentic to the science discipline (Goldman et al., 2016; Houseal et al., 2016; NGSS Lead States, 2013; NRC, 2012). Additionally, I gained an understanding that the PCK of teachers can be impacted without direct experiences in professional development opportunities. Through Kaitlyn’s actions I was able to appreciate how collaboration with a colleague who has experienced professional development opportunities can allow for the transfer of learning to positively impact pedagogical knowledge and therefore PCK
Participants in the research study did not abandon the use of content area literacy instruction. I initially viewed literacy instruction as a dichotomy between content area and disciplinary literacies (Herber, 1970; Moje, 2008, 2015; Shanahan & Shanahan, 2008, 2015). As I observed all three participants using components of content area literacy instruction to build disciplinary literacy skills, I comprehended the need for balance between content area and disciplinary literacy instruction (Brozo et al., 2013; Faggella-Luby, et al., 2012). Kaitlyn began with content area literacy skills to aid Grade 6 students in interacting with science texts and then gradually introduced disciplinary literacy tasks that focused on the presented phenomenon. Melanie used content area literacy assignments throughout the unit of instruction to support ongoing development of summarization skills and vocabulary development that could contribute to classroom learning. Debra incorporated marking the text and study of word roots and origins to build understanding of the context for science learning. I viewed how each of these content area literacy instructional strategies contributed to the development, planning, and implementation of multiple dimensions of science instruction that included authentic, disciplinary literacy instruction (Brozo et al., 2013; Faggella-Luby et al., 2012).

Throughout the study, I was able to witness the complexity of literacy instruction in the science classroom and the necessity for interactions of literacy and science skills and practices (Houseal et al., 2016; Norris & Phillips, 2003). This complexity allowed me to see the need the need for teachers to prepare students with the skills necessary for interacting with information to construct knowledge. As Norris and Phillips (2003) described, students must possess the fundamental literacy knowledge that can then be used to construct derived literacy knowledge.
The need for fundamental literacy knowledge may require teachers to teach skills associated with content area literacy instruction as a means for preparing students for engagement in opportunities for acquiring and constructing derived literacy knowledge (Brozo et al., 2013; Faggella-Luby et al., 2012; Norris & Phillips, 2003).

The need for both fundamental and derived literacy in learning disciplinary knowledge became apparent and indicated the need for teachers to recognize levels of literacy skills in students (Norris & Phillips, 2003). I developed an understanding of student literacy skills that encompass both content area and disciplinary literacy skill and allows teachers to determine instructional choices such as scaffolds for student learning (Faggella-Luby et al., 2012). Thus, teachers may be required to incorporate both content area literacy instruction to build fundamental literacy skills prior to disciplinary literacy instruction that aids in derived literacy skill and knowledge (Brozo et al., 2013; Faggella-Luby et al., 2012; Norris & Phillips, 2003). After identifying literacy skills in students, teachers must possess or develop knowledge and pedagogy for scaffolding appropriate learning (Faggella-Luby et al., 2012).

Throughout the study, I viewed the incorporation of both content area and disciplinary literacy instruction as requiring PCK for literacy instruction in science classes (Shulman, 1986, 1987). I witnessed teachers in the process of developing PCK that addressed student need in the areas of literacy and science. Teachers would be integrating and using their knowledge of students, content area and disciplinary literacy practices, science pedagogy, and science content and practices (NGSS Lead States, 2013; Shulman, 1986, 1987). I learned from participants in the study as the participants continued teaching content area skills to students to address the fundamental literacy skills of students, but also provided opportunities for application of literacy in disciplinary contexts (Fisher & Ivey, 2005; Moje, 2008, 2015; Norris & Phillips, 2003;
Shanahan & Shanahan, 2008, 2015). This integration supports the varied or balanced approaches described by Brozo et al. (2013) and Faggella-Luby et al. (2012) to meet the needs and scaffold learning of necessary skills for constructing both literacy and science skill and knowledge.

**Interpretation of Findings**

Three participants implemented disciplinary literacy instruction to varying degrees within their science instruction. Various factors influenced approaches to integrating literacy instruction resulting in various activities that engaged students in literacy application as part of science learning. Three themes emerged from the data analysis to support varied implementation of disciplinary literacy. These themes centered on events that altered teacher preparation and approaches to planning and included prior teaching experiences, professional learning experiences, and curricular changes resulting from state and district adoption of NGSS.

**Prior teaching experience.** Research articulated that prior teaching experience impacts PCK by providing past interactions, situations, content, and pedagogical implementations upon which a teacher can draw to determine in the moment or future responses (Shulman, 1986, 1987). When considering implementation of literacy instruction, prior teaching experience played a dual role in developing PCK for disciplinary literacy instruction in the science classrooms of participants. Teacher choices for moving toward disciplinary literacy could be impeded by prior literacy experiences centered on content area literacy strategies (Fisher & Frey, 2008; Fisher & Ivey, 2005). However, experience using content area strategies that were viewed by teachers as incongruent with science instruction could serve as an impetus for change to disciplinary literacy (Fisher & Ivey, 2005; Shanahan & Shanahan, 2008, 2015). Additionally, lack of experience represents a limited source of information to inform PCK and decision-making of novice teachers (Shulman, 1986, 1987).
Initially speaking of literacy instruction and NGSS, Kaitlyn viewed expectations of NGSS as limiting her ability to teach literacy instruction. She struggled with timing direct instruction of content vocabulary and general reading strategies prior to or throughout science learning. Kaitlyn had previously approached literacy instruction in science through content area strategies learned in her master’s degree coursework and subsequent professional development experiences. These experiences formed the basis of literacy instruction for nearly 12 years of science teaching and needed to be overcome to develop PCK for disciplinary literacy instruction in science. Support for Kaitlyn to change her PCK to meet transitions in approaches to science instruction was provided through collaboration with a grade level colleague. Application of learning from her colleague allowed Kaitlyn to build disciplinary literacy experiences upon which she could reflect to further enhance her disciplinary literacy PCK in science. Kaitlyn’s development is consistent with research that supports the development of PCK through professional learning experience and interactions (Daehler et al., 2015; Park et al., 2011; Shulman, 1986, 1987).

In contrast to Kaitlyn’s prior experience that represented a challenge to developing disciplinary literacy PCK, Melanie’s introduction to disciplinary literacy allowed her to expand her PCK to align disciplinary literacy and science instruction. Melanie viewed literacy as important in science as a means for discovering and communicating information but did not find content area literacy strategies conducive to science instruction and therefore limited in application. Fisher and Ivey (2005) expressed a similar position that the lack of literacy achievement due to content area literacy resulted from inconsistent and limited implementation by science teachers. Melanie’s view of limitations in content area literacy instruction produced a willingness to embrace learning of disciplinary literacy that enhanced her PCK leading to
implementation of new pedagogy better aligned with Melanie’s teaching style (Shulman, 1986, 1987).

While Kaitlyn and Melanie had different initial reactions to disciplinary literacy, both participants engaged in efforts to develop PCK and transition to methods that re-emphasized literacy as authentic to the science discipline. Throughout the progression of altering PCK to meet curricular demands and student needs, Kaitlyn and Melanie had prior experience on which they could fall back, if necessary. These experiences separated Kaitlyn and Melanie, both veteran teachers, from Debra, a novice teacher in only her second year of teaching. Debra felt limited by a lack of teaching experience, stating she only had one course that pertained to literacy and that this course was not specific to science. Due to a lack of background experience in teaching, Debra’s PCK was based on experiences she had as a student. These experiences were based on content area literacy instruction and Debra stated that her decisions reflected the methods that worked best for her as a student. Debra was not resistant to modifying or developing her PCK but lacked prior teaching experiences to drive changes as evidenced in Melanie’s transition. Additionally, Debra did not have the opportunity to collaboratively plan with a colleague who had knowledge of instructional transitions to overcome prior literacy conceptions as exhibited by Kaitlyn. Professional learning experiences could aid in developing Debra’s PCK (Daehler et al., 2015; Park et al., 2011; Shulman, 1986, 1987).

Professional learning experience. Kaitlyn and Melanie were influenced by professional learning experiences inclusive of NGSS and disciplinary literacy learning offered by faculty at a local university. Melanie directly participated in the learning opportunity and was in her third year of engaging in learning about and planning for instruction aligned with NGSS and including disciplinary literacy instruction. She attributed her developing understanding of literacy in
science to the professional development. As presented by Daehler et al. (2015), Park et al. (2011), and Shulman (1986, 1987), professional learning followed by application in planning and instruction resulted in shifts within PCK. Melanie expressed this as she stated her use of literacy increased in frequency and more directly supported student learning as a result of her engagement in the professional learning experience.

Kaitlyn did not directly participate in the professional learning experience but benefited from it due to her collaboration with a grade level colleague who had participated in the professional development. As previously described, Kaitlyn was initially skeptical of and resistant to approaches she thought detracted from literacy. However, after her collaborative planning efforts, she voluntarily implemented instruction aligned with her colleague’s learning from the professional learning experience. Collaboration and practice of pedagogical changes resulted from professional learning and a willingness to embrace changes, at least as an initial trial of new learning. Consistent with Shulman’s (1986, 1987) findings that revealed experience influenced PCK, Kaitlyn’s use of disciplinary literacy instruction provided experiences that, over time, shaped her evolving PCK, resulting in increasing uses of disciplinary literacy integrated with science instruction.

Changes in PCK described and exhibited by Melanie and Kaitlyn could be related to professional development experienced directly at a local university and communicated through collaboration with a colleague. The professional learning experience served the purpose of aiding PCK development, both in addressing pedagogical need and in overcoming limitations of prior experiences. As participants engaged in planning and implementing lessons and units aligned with NGSS and inclusive of disciplinary literacy, participants became comfortable in utilizing approaches that provided opportunities for engaging students in literacy, science practices, and
learning of content consistent with three-dimensional instruction outlined in NGSS (NGSS Lead States, 2013).

**Curricular change to NGSS.** At the time of the study, participants were preparing for upcoming transitions to curriculum that aligned with NGSS. The NGSS (NGSS Lead States, 2013) and NRC (2012) framework presented recommendations for structuring instruction around content, practices, and crosscutting concepts. Houseal et al. (2016) related these three dimensions of NGSS instruction to disciplinary literacy. As participants progressed in their understanding of NGSS and development of associated instructional practices, disciplinary literacy became embedded in science instruction. Participants planned instruction to engage students in science and engineering practices and crosscutting concepts to learn content presented in the curriculum used by the district at the time of the study (NGSS Lead States, 2013).

Houseal et al. (2016) described the implementation of instruction in science as a combination of content knowledge, unifying themes, and practices. As participants began to view science instruction in similar ways, uses of literacy re-emphasized application within science learning. Participants planned learning opportunities that used literacy as a component in scientific practices centered on a phenomenon, such as causes and effects of declining barn owl populations in Kaitlyn’s class, body systems in the role of life in Melanie’s class, or determining possible offspring of dogs in Debra’s class. The use of phenomena was consistent with learning about NGSS and provided a means for disciplinary literacy use as presented by Goldman et al. (2016). Even without explicit planning for disciplinary literacy, participant indications of literacy in planning became increasingly focused on applications driven by multi-dimensional science instruction (Berland & Reiser, 2008; Goldman et al., 2016; Houseal et al., 2016; NGSS Lead States, 2013).
The act of teaching science through a phenomenon that prompted questions or presented a problem to be solved was fostered through in-district training and the development at the local university. The idea of using a phenomenon represented an impetus for changes in science PCK of participants that allowed literacy to be viewed differently within science instruction. Literacy became a series of tools within science practices that fostered content learning through the use of various sources integrated and synthesized in the process of constructing knowledge (Goldman et al., 2016; Norris & Phillips, 2003). Participant engagement in learning about and implementing NGSS-inspired lessons allowed for a view of literacy consistent with disciplinary literacy and therefore integrate literacy as used by experts in the science discipline (Goldman et al., 2016; Shanahan & Shanahan, 2008, 2015).

The instructional transitions being learned and implemented by participants in efforts to meet the expectations of NGSS provided context for re-emphasizing literacy as authentic to the science discipline through science and engineering practices. Classrooms became communities that practiced science and therefore integrated literacy in ways that were relevant to these science practices (Goldman et al., 2016; Houseal et al., 2016; Shanahan & Shanahan, 2008, 2015). Uses of literacy aligned with the recommendations of Moje (2008, 2015) and Shanahan and Shanahan (2008, 2015) as participants engaged in creating authentic learning experiences in science. The alignment of literacy and content instruction resulted in literacy being taught in ways consistent with uses in the discipline. As participants planned instruction to engage students in science practices and content, teaching naturally integrated disciplinary literacy (Houseal et al., 2016; NGSS Lead States, 2013).
Implications

Changes in science instruction represented in NGSS (NGSS Lead States, 2013) and the NRC Framework (2012) coupled with research that identified deficiencies in the content area literacy approach (Fisher & Ivey, 2005; Moje, 2015; Shanahan & Shanahan, 2008, 2015) have resulted in calls for re-emphasizing literacy instruction in science as applicable to science practices. This integration of disciplinary literacy use has been advocated by scholars such as Moje (2007, 2015) and Shanahan and Shanahan (2008, 2015) as a means of creating meaningful literacy connections by fostering uses consistent with authentic applications of literacy in the broader science discipline. Teachers can design and implement instruction that uses literacy to support science practices of obtaining, evaluating, and communicating information, developing and using scientific models, investigating, arguing from evidence, and solving problems (NGSS Lead States, 2013). Faggella-Luby et al. (2012) recommended balancing content and disciplinary literacy instruction to meet the needs of students while Shanahan and Shanahan (2008, 2015) focused on approaches rooted predominantly in disciplinary literacy. The focus of this study was on exploring how science teachers applied their understanding of reading, writing, and speaking and listening components of literacy in science instruction.

While research recommends the re-emphasis of disciplinary literacy approaches, there has been a lack of research exploring how science teachers implement such an approach, especially as science teachers consider the implementation of NGSS. The assertion of literacy as an important component of science instruction presented by Norris and Phillips (2003) has informed the NRC (2012) framework and resulting three-dimensional learning structures of NGSS (NGSS Lead States, 2013). Similarly, Stage et al. (2013) indicated a need for disciplinary literacy to improve communication and use of evidence in science instruction, but also identify a
lack of common language and tools for facilitating literacy instruction in science classrooms. McArthur (2012) posited that pedagogy needs to be aligned with practices of disciplinary experts, thus incorporating science and engineering practices as outlined by Houseal et al. (2016). In addition to focusing on reading, writing, and speaking and listening components of literacy, this study considered science and engineering practices in disciplinary literacy instruction in science to explore the integration of literacy and content and implementation by science teachers. This exploratory study resulted in the identification of implications for the scholarly research and literature on disciplinary literacy in science, impacts on policy and decision-making, and improvements for professional practice.

Implications for scholarly research and literature. Fisher and Ivey (2005), Moje (2015), and Shanahan and Shanahan (2008, 2015) presented the need for changing literacy instruction in the teaching of subject areas as content area literacy practices have not resulted in expected advancements in student understanding and achievement. Knowledge of disciplinary literacy in science is essential for meeting the recommendations for re-emphasizing literacy instruction in the science disciplines as presented in the literature. This study explored teacher PCK and actions related to the implementation of disciplinary literacy and can therefore add to the knowledge of disciplinary literacy instruction in the science discipline. First, this study explored teacher views of disciplinary literacy that can impact knowledge of instruction in science. Secondly, the findings of the study can improve knowledge through examples of methods or pedagogy for implementing disciplinary literacy. The study also adds to knowledge by connecting disciplinary literacy to science content and standards. Finally, the exploration of this study can add to knowledge that support transitions from conceptions of disciplinary literacy to classroom practices.
This study explored teacher experiences with and views of disciplinary literacy in science instruction. While Fisher and Ivey (2005) identified a lack of teacher understanding and willingness to implement content area literacy as an impediment to literacy instruction in disciplines, participants in the study viewed literacy as important to the acquisition and understanding of science concepts. However, participants were developing their understanding of disciplinary literacy as related to science instruction. This is consistent with a lack of research explaining pedagogy for implementing disciplinary literacy (Fisher & Ivey, 2005; Moje, 2015; Shanahan & Shanahan, 2008, 2015). By exploring planning and implementation of science lessons and literacy within these lessons, knowledge about teacher views of disciplinary literacy can add to knowledge about disciplinary literacy. In the context of this study, participants from the urban middle school viewed literacy as interpretation of varied sources to provide information for learning about science content. The use of literacy for analysis and interpretation to support science content learning and practices is consistent with research for engaging students in science (Enfield, 2014; McClune et al., 2012) and for building science practices and knowledge through inferencing, interpretation, and analysis (Clinton & van den Broek, 2012; Linderholm et al., 2014; Piercy & Piercy, 2011; Yager, 2004; Yore, 2004).

After exploring science teacher understanding of disciplinary literacy to create opportunities for students to construct understanding of science, methods for delivering disciplinary literacy instruction are necessary for student learning. Knowledge of teacher understanding can then be related to practices that implement science instruction in support of literacy applications in science. Practices of science teachers can demonstrate pedagogies, such as reading varied texts that include written text, graphs, charts, data sets, diagrams, short and long term writing in summaries, lab reports, and models, and speaking and listening to give and
receive feedback fostered through small and large group discourse. These practices incorporated into pedagogies can be considered for implementation in the broader context of science classrooms outside of the cases included in the study.

At the time of the study, participants were in the process of transitioning instruction to meet expectations presented in NGSS (NGSS Lead States, 2013). Even as participants were planning lessons that facilitated instruction aligned with NGSS, they viewed literacy as an important component of science teaching. As a result, participant development of PCK for science and literacy instruction were being refined or developed. While one participant initially expressed concerns about the structure of NGSS and the integration of literacy instruction, development opportunities and collaboration allowed for changing approaches that demonstrated a knowledge of literacy as applied within the practices of science. As Houseal et al. (2016) described, the implementation of NGSS instructional dimensions that included content, practices, and crosscutting concepts (NGSS Lead States, 2013) allowed participants to address disciplinary literacy in the science discipline.

The growing familiarity with NGSS and disciplinary literacy provided a context for participants who moved disciplinary literacy from conceptualization to practice. As documented in this study, participant implementation of disciplinary literacy grew from professional learning and personal experiences related to NGSS and disciplinary literacy. The response of participants to learning demonstrates the development of PCK resulting in practices that move disciplinary literacy from the conceptualization presented by Moje (2015) and Shanahan and Shanahan (2008, 2015) to practical implementation in the classroom as supported by Houseal et al. (2016). The knowledge of practice from this study can support a growing understanding of how
disciplin ary literacy can be implemented in science instruction to support both student learning opportunities for both literacy and science content.

**Implications for policy and decision-making.** Science teacher understanding is crucial in the implementation of disciplinary literacy to improve student application of skills to learn content (Moje, 2015; Shanahan & Shanahan, 2008, 2015). Teacher understanding of authentic literacy that is consistent with uses by experts in the field of science can aid in the advancement of lessons that build literacy use by students in the science classroom, thus aligning science instruction with current science standards (Houseal et al., 2016; NGSS Lead States, 2013). To improve policy and decision making in disciplinary literacy and science instruction, the understanding of disciplinary literacy can be expanded beyond classroom routines to inform systems of literacy instruction, facilitate the integration of practices that move from content area literacy approaches to disciplinary literacy instruction, and support connections of NGSS with disciplinary literacy instruction in science.

Drawing from an improved understanding of literacy by science teachers and in science classrooms as described through knowledge added to the field of disciplinary literacy research, disciplinary literacy knowledge can be applied to inform policy and decision-making processes. This broader understanding of disciplinary literacy can be used in making decisions that define literacy within the science classroom. Definitions of literacy in science can influence policies for instruction and evaluation of instructional practices. The integration of literacy into science practices can then inform efforts that connect literacy and science instruction within the context of science standards such as NGSS being considered by participants of the study. Both teachers and administrators can utilize findings of this study to initiate discussion of teacher practices that can integrate literacy instruction within discipline-specific subject instruction.
Shanahan and Shanahan (2008, 2015) advocated making decisions that move away from instruction that emphasizes generalized strategies of content area literacy instruction to disciplinary literacy instruction that is consistent with uses of literacy by disciplinary experts. Faggella-Luby et al. (2012) viewed instruction as a balance between content area and disciplinary literacy instructional practices that is responsive to student need. The viewpoints of Shanahan and Shanahan (2008, 2015) and Faggella-Luby et al. (2012) can impact decisions about instructional approaches pertaining to literacy instruction. As teachers, administrators, and other policy-makers consider best practices for literacy instruction, decisions can be supported by a growing understanding of instructional practices that support literacy instruction (Fisher & Ivey, 2005; Moje, 2015; Shanahan & Shanahan, 2008, 2015). This study provides descriptive data that relate instructional decisions within practices of middle school science classrooms that could inform broader decisions about methods for implementing disciplinary literacy instruction in the context of science teaching and learning.

One instructional decision to be considered for disciplinary literacy instruction in science is the provision of development opportunities and support for both processes of implementation and evaluation of disciplinary literacy instruction. As Daehler et al. (2015) and Park et al. (2011) described, PCK can be developed through professional development. Therefore, instructional practices, including pedagogy and content knowledge of disciplinary literacy in science, can be developed. Two participants acknowledged the influence of development experiences on their integration of literacy and science content teaching aligned with NGSS through the application of the three dimensions of instruction (Houseal et al., 2016; NGSS Lead States, 2013). Stemming from the positive impacts of professional development indicated by participants of this study, decision-making can support professional development opportunities. In addition, organizational
structures, often established through formal or informal policies, must be present to support continued development and application of PCK and the dissemination of knowledge that leads to improved PCK (Daehler et al., 2015; Park et al., 2011; Shulman, 1998).

As PCK for disciplinary literacy in science is developed, policies can support an instructional transition that allows for the re-emphasis of literacy as relevant in disciplinary contexts (Moje, 2015; Shanahan & Shanahan, 2008, 2015). Curricular decisions that support the implementation of disciplinary literacy are often established at higher institutional levels than individual classrooms. While this study focused on successes of and challenges to teacher actions that support disciplinary literacy instruction in science classrooms, learning from teacher actions and classroom implementation can inform policies that sustain successes of and address challenges to implementation of disciplinary literacy.

Supporting successes of disciplinary literacy instruction may include the creation of curricula and development opportunities that allow teachers to connect expectations of science standards, such as NGSS, with disciplinary literacy applications in the science classroom. Participants in the study were able to connect science practices with literacy skills when planning and implementing instruction. Through the presentation of phenomena or questions that spurred learning, participants created authentic opportunities for the learning and use of literacy skills. To aid students in the progression of application of skills, participants balanced disciplinary literacy instruction with content area literacy instruction as recommended by Faggella-Luby et al. (2012). However, as students became more engaged with science and engineering practices to investigate science concepts, literacy instruction in science became more focused on disciplinary literacy as presented by Shanahan and Shanahan (2008, 2015) and aligned with the work of McConachie (2010).
Implications for improving professional practice. Moje (2015) and Shanahan and Shanahan (2008, 2015) suggested that improving professional practice include approaches to literacy instruction that are relevant to students and authentic to disciplinary instruction. Explorations of science teacher practice contained within this study provide evidence for supporting and improving practices related to literacy instruction in science. Science teacher professional practices can be improved through understanding the forms of text used by scientists, the re-emphasis of literacy as integrated through the three-dimensions of instruction outlined by NGSS (Houseal et al., 2016; NGSS Lead States, 2013), and the application of professional learning to support developing PCK for disciplinary literacy instruction in science.

Practice in implementing disciplinary literacy in science can be improved as science teachers adopt an expanded definition of text to include forms used by experts within the science discipline. In addition to textbooks and other traditional written texts such as articles, participants in the study included graphs, charts, diagrams, and data sets as text. The broad definition of text and the use of text for driving science practices of inference, analysis, and interpretation are consistent with recommendations for improving literacy instruction and practice within the science discipline (Anders & Guzzetti, 2005; Anderson, 1999; Linderholm et al., 2014; Norris & Phillips, 2003; Vellom & Anderson, 1999). As science teachers understand a broader definition of text that includes the varied sources of information used in science, teacher approaches to literacy can become more aligned with science practices and therefore with disciplinary uses of literacy as advocated by researchers (Fisher & Ivey, 2005; Moje, 2015; Shanahan & Shanahan, 2008, 2015).

Building from a broader definition of text, science teachers can become advocates for the use of information in science that parallels the practices of experts in the field. By understanding
the processes of literacy as inclusive of obtaining and communicating information in the science discipline, science teachers can improve their pedagogy to allow for the planning and implementation of experiences that incorporate literacy instruction and use within the science classroom (DiDomenico et al., 2017). As Houseal et al. (2016) suggested, the connections between the three dimensions of science instruction presented in NGSS can facilitate the implementation of disciplinary literacy. As participants transitioned their instruction to align with NGSS principles and content, disciplinary literacy instruction became an increasingly regular component of planning and instruction, allowing them to navigate the complexities of school-wide literacy goals while supporting specific content learning.

Additionally, an understanding of disciplinary literacy and connections to NGSS as presented by Houseal et al. (2016) can prepare science teachers to engage in developing science teaching practices with regards to literacy instruction. Two participants in the study reported positive influences of professional development on their approaches to literacy and science instruction. This is consistent with the research of Daehler et al. (2015) and Rozenszajn and Yarden (2014) that reported professional development experiences as opportunities for learning and developing both content knowledge and PCK. Professional development can lead to both adaptation of current professional practice to meet identified needs and to the advancement of new approaches to theory and practice (Rozenszajn & Yarden, 2014). As science teachers learn the content of disciplinary literacy and develop pedagogy for implementing disciplinary literacy, professional practice for disciplinary literacy instruction in science can be improved because of more fully developed PCK of the science teachers.

Classroom implementation of disciplinary literacy should consider the balance necessary for students to gain literacy skills that can be applied in the classroom (Faggella-Luby et al.,
Teacher practice can incorporate opportunities for developing general literacy skills when appropriate in order to allow for subsequent application in science learning and communication. As Faggella-Luby et al. (2012) suggested, teachers must know student literacy needs to develop and apply literacy pedagogy. By understanding the connectedness of science and engineering practices and disciplinary literacy, teachers can improve PCK and practice to support student learning and use of both content area and disciplinary literacy skills (Faggella-Luby et al., 2012).

As teachers develop an understanding of disciplinary literacy, connections between literacy and content expectations can be developed to align instruction with the knowledge and practices used by discipline experts, moving from conceptualization of disciplinary literacy to classroom practices that support balanced opportunities for learning. Policies and decision making can support teacher efforts in defining disciplinary literacy and developing disciplinary literacy PCK for science instruction. As PCK is cultivated, science teachers can improve professional practices that are expressed through planning and implementation of lessons that support uses of literacy in science consistent with uses by expert scientists.

**Unexpected outcomes.** Disciplinary literacy instruction in the science classroom was the focus of the study and included three participants in a Grades 6-8 urban middle school. One sub-question of the study concentrated on participant prior knowledge and experience with disciplinary literacy instruction as well as relevant training or development opportunities. This question resulted from the work of Shulman (1986, 1987) that presented experience and training as two factors that impact PCK. However, in this study, the participants with the most teaching experience also had more opportunities for attending training and professional development on disciplinary literacy instruction. Since disciplinary literacy is a contemporary framing of literacy
instruction in science as proposed by Moje (2015) and Shanahan and Shanahan (2008, 2015), the expectation was that teachers who recently completed college training may have more exposure to disciplinary literacy techniques than veteran teachers. In this study, the beginning teacher had fewer years teaching experience as expected, but also had fewer opportunities to learn about disciplinary literacy instruction in preservice coursework. Therefore, the participants with the most teaching experience also had more opportunities to learn about disciplinary literacy, thus confounding the variables of experience and training.

Instructional variations also occurred due to different students and a range of student needs and personalities. Even when observing the same lesson implemented by the same participant, there were differences in the delivery and in the student reactions. To aid in explaining these variations, post-lesson interview questions were structured to elicit participant perceptions and reasoning for different approaches and the varied reactions and readiness of students. Data from these interviews were used to explore and explain observations.

**Suggestions for Future Research**

Future research should address the impacts of disciplinary literacy instruction on student learning. This study focused on implementation of disciplinary literacy from the perspective of teacher actions but did not study the impacts on student learning. Study of student learning could include quantitative measures of content learning through assessment of science knowledge and practices and on the understanding and application of literacy skills. A related area of future research could explore student engagement in science practices and uses of literacy within these practices. Exploration of student engagement in science practices could include investigations of the impacts on transitions of science instruction that align with recommendations of NGSS and
related uses of disciplinary literacy as authentic to the three-dimensions of NGSS instruction reported by Houseal et al. (2016).

In addition to future research focused on students, additional research could concentrate on differentiating the impacts of teacher experience and professional training on the implementation of disciplinary literacy. In the study, the participants with the most years of teaching experience were also influenced through professional development experiences. Differentiating these components can provide improved understanding of the individual impacts of professional learning and experiences on PCK, particularly related to disciplinary literacy PCK of science teachers. With an improved understanding of components that impact the development of PCK, policy and decision-making processes can be structured or modified to better support opportunities for teachers that translate into better quality planning and instruction for disciplinary literacy instruction in science classrooms.

Finally, future research can focus on expanding the exploration beyond the boundary of science to focus on disciplinary literacy instruction as it impacts a diversity of content areas. While Lent (2015) provided an overview of disciplinary literacy in different subject areas, explorations of classroom practices in different educational settings and subject areas could aid in providing teachers with relevant methods for improving practices to meet student need in both content and literacy. Explorations of disciplinary literacy in other disciplines may allow for analyses that compare disciplinary literacy in different contexts to present similarities and differences based on subject area and grade level, therefore impacting a broader audience.

**Limitations and Reflexivity**

Qualitative case studies provide data that support answering questions such as the research question investigating how science teachers implement disciplinary literacy instruction
The use of multiple sources of data, member checks, and triangulation of data sources and literature aided in the analyses of data to produce reliable conclusions. However, limitations of the study existed and included a focus on middle school Grades 6-8, a site with established school-wide literacy goals, participants with a literacy focus, all participants who were science teachers, and time constraints due to the researcher’s program of study. The researcher understanding of connections between disciplinary literacy and NGSS evolved through the study and data analysis.

The research study focused on how middle school science teachers at a Grades 6-8 urban middle school implemented disciplinary literacy instruction in science classrooms. The study included three participants representing three cases. One case focused on Grade 6, one on Grade 7, and one on Grade 8. However, all three cases were within a single urban middle school. This limitation resulted due to convenience for the researcher to access the site. As described by Stake (1995), the site selected for a qualitative case study should be accessible to the researcher, including geographical accessibility.

In addition to all three cases being from a single site, the school chosen as the site had both school-wide and district goals to improve student achievement in literacy. This resulted in an awareness of literacy, although not necessarily disciplinary literacy. Additionally, literacy goals required administrators and teachers to evaluate tools for improving literacy skills and the effectiveness of these tools or methods. The selection of the site limited data to middle school science classrooms in an institution with awareness of and focus on literacy instruction and student achievement. When considering the selected site and resulting data, all three participants had an awareness of literacy and literacy was a component of planning to align with school goals. Therefore, the study is limited to teachers with an awareness of general literacy.
This study focused on implementation of disciplinary literacy in science classes and all participants were science teachers. Even though disciplinary literacy can be applied to all disciplines, one boundary of this study included a focus on implementation of disciplinary literacy in the science discipline. Data collection took place during a nine-week period to align with the doctoral program timeline (Appendix J). Therefore, the findings, conclusions, and interpretations of this study are bounded by the implementation of disciplinary literacy in science classrooms within the time frame of the study.

Data collection protocols were not field tested but were reviewed for validity. Content experts in literacy and science reviewed the interview, observation, and document review protocols for face and construct validity. The expert review determined that the protocols were aligned with the major components of literacy and science instruction. A methodologist expert reviewed the protocols for alignment with the qualitative case study methods prior to use of the protocols in the field. These expert members of the doctoral dissertation committee were essential in verifying the validity of the protocols.

A final limitation is the length of the study. Data collection was confined to a nine-week period that encompassed one instructional unit in each grade level. Data collection was limited due to the timeline of the program of study of the researcher. Even though data collection was limited to a predetermined period, a saturation of data as described by Bogdan and Biklen (2007) was reached that allowed for analysis and interpretation of findings.

The researcher has a background in science education, is a practicing state-certified science teacher at the time of the study, and was trained in NGSS, thus providing familiarity with science content and pedagogy aligned with NGSS. While the researcher had experience with NGSS and science instruction, the implementation of literacy as a component of NGSS
instruction was not present in prior training sessions. As the study progressed, connections between NGSS and disciplinary literacy became more apparent to the researcher throughout data collection and analysis.

Throughout the research study, the researcher learned the enormity of the task of undertaking a qualitative research study and the processes required to gather data through methods that were minimally intrusive for participants. The study allowed the researcher to view varied perspectives of disciplinary literacy and then synthesize and communicate the learning from the study. The completion of this traditional five-chapter dissertation incorporated the learning and use of accepted data collection and reporting methods.

The completion of the study illustrated the importance of engaging with expert colleagues to form and guide research. The doctoral dissertation committee provided expertise throughout the proposal, data collection, and analysis and reporting phases of the research study. The researcher learned from the guidance of the committee in order to improve the understanding of scholarly research studies. This learning will allow the researcher to better access the scholarly community as a contributing member who both consumes and produces valuable knowledge for the field of education.

The researcher identified rapport with participants as a component of the research study that worked well. The participants of the study had different personalities, but all interacted with the researcher in a positive and professional manner. The participants agreed to participation in the study and responded well to prompts during interviews. Participants shared information that provided insight into thought processes related to disciplinary literacy PCK.

As part of the learning process, the researcher has reflected on the experience and identified factors that would be done differently in the future. First, the researcher identified that
technology could aid in the process of coding data for analysis. An unfamiliarity with the available technology precluded the use of software in this study. However, working to build familiarity and understanding can facilitate future research. Secondly, future research could provide opportunities to gather data from multiple sites to gain a broader perspective of teacher actions. The research was limited to a single site to aid in accessibility but could be opened to science teachers from different sites if a similar study is completed in the future. Lastly, the researcher would employ a mixed methods study in the future to provide a measure of growth of teacher PCK. This study focused on exploring science teacher PCK, did not measure the growth or development of PCK. Future research could gauge teacher PCK of disciplinary literacy in science prior to initiating a unit of study and at the conclusion of the unit of study. This comparison could be used along with qualitative case study data to describe the change or lack of change in science teacher PCK.

Limitations of the study are acknowledged and delineated to provide context for data collection and analysis. The limitation of a site with a focus on literacy goals is relevant in understanding findings as participants were aware of and planned for integration of literacy across disciplines. The case studies were bounded by subject area to focus on disciplinary literacy in science and were limited to Grades 6-8 contained within the selected site. While this study was limited by the researcher’s program of study, saturation of data was reached within the time frame for data collection.

Chapter Summary

Impacts of new standards and ongoing recommendations to include literacy throughout instruction in the disciplines led to an implementation of literacy instruction termed disciplinary literacy. Disciplinary literacy calls for literacy instruction that aligns with uses of literacy in each

However, much of the research on disciplinary literacy focused on the conceptual basis of the approach and not on implementation of instruction. Consistent with the calls of Fang and Coatoam (2013), this study focused on the implementation of disciplinary literacy instruction in science classrooms. A qualitative multiple case study design guided the exploration of how three middle school science teachers implemented disciplinary literacy instruction in Grades 6-8 at an urban middle school in the United States. Data were collected and analyzed within each case and between cases through cross-case analysis. Major findings and conclusions of the study included participants drawing on their prior experiences and new learning to include reading, writing, speaking and listening, and science and engineering practices. Participants having a broad view of text, including diagrams, tables, charts and graphs, allowed the use of reading to in diverse ways in the science discipline. Writing was implemented through activities that required summarization and communication of information and was exhibited in various forms that included written text and scientific models. Speaking and listening skills were taught and practiced through scientific modeling and discourse activities. Finally, participants planned lessons that were increasingly inclusive of science and engineering practices that provided context for the authentic use of disciplinary literacy. Based on the major findings and conclusions, prior teaching experience can either impede or further the development of PCK as teachers with experience using content literacy were either comfortable with current approaches or eager to find differing opportunities for engaging students in literacy. Professional development can impact teacher ability to implement disciplinary literacy. Furthermore, disciplinary literacy practices can be supported by changes in science instruction, such as through NGSS that incorporate the use of science and engineering practices in instruction.
Implications of this study include adding knowledge to the field of disciplinary literacy instruction in science, impacts on decision-making for literacy instruction in science, and improving professional practice of science educators. This study added knowledge to the field of disciplinary literacy by describing teacher views of disciplinary literacy, methods or pedagogy for implementing disciplinary literacy, connecting disciplinary literacy to science content and standards, and supporting transitions from conceptions of disciplinary literacy to classroom practices. Additional contributions to the field of disciplinary literacy can impact decision-making as teachers, administrators, and researchers improve their understanding of disciplinary literacy. An improved understanding of disciplinary literacy can be extended beyond classroom routines and inform systems of literacy instruction. Changes in literacy instruction can facilitate the re-emphasis of literacy in the discipline. A focus on disciplinary literacy instruction can support connections to NGSS or other standards to improve disciplinary literacy instruction in science. Implications for professional practice of science teachers include an understanding the forms of text used by scientists, the re-emphasis of literacy as integrated through the three-dimensions of instruction outlined by NGSS (Houseal et al., 2016; NGSS Lead States, 2013), and the application of professional learning to support developing PCK for disciplinary literacy instruction in science.

Future research can include additional longitudinal studies of disciplinary literacy that include the impacts of disciplinary literacy instruction on student learning and move beyond the focus of this study on teacher actions. Further research on teacher actions could investigate the impacts of differing teacher experiences and training on the implementation of disciplinary literacy. Finally, future research can include a broader focus that includes other disciplines and moves beyond the focus of disciplinary literacy instruction in science.
This study was limited by a focus on middle school science teachers in an urban middle school. Further limitations included time constraints due to the researcher’s program of study. The researcher understanding of connections between disciplinary literacy and NGSS progressed throughout the study and analysis of data.
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Appendices
Appendix A: District Permission for Research
Hello Corey, I am so glad to hear the great news regarding your professional endeavors and you absolutely have my full approval of your request... all the best.

Elisa Soble, Superintendent
Balboa Public Schools
Tel: 858-154-7987
C: 858-88-3839
elsasoble@balboaschools.com

I am continuing to work toward earning my Ed. D. and have reached the planning and dissertation phase of my work. The topic that I have chosen to investigate is the implementation of disciplinary literacy in secondary science classrooms. My focus will be on teacher actions and thoughts and will not involve students or student work. Data will be collected through observations and interviews. All data will be reported without district and teacher identifiers. I am writing to request permission and support for recruiting participants from Bristol middle schools for inclusion in this study.

Thank you,
Corey Nagle

Privileged and confidential. If received in error, please notify me by e-mail and delete the message.
Appendix B: IRB Letter of Approval
Mr. Corey Nagle

Dear Mr. Nagle:

The Institutional Review Board (IRB) for Human Research Participants Protection has completed its review of your proposal number IRB 2018-057 titled, "A multiple case study of disciplinary literacy instruction in secondary science classrooms," as it relates to the protection of human participants used in research, and granted approval for you to proceed with your study on 10-19-2017. As a research investigator, please be aware of the following:

* You will immediately report to the IRB any injuries or other unanticipated problems involving risks to human participants.

* You acknowledge and accept your responsibility for protecting the rights and welfare of human research participants and for complying with all parts of 45 CFR Part 46, the UWF IRB Policy and Procedures, and the decisions of the IRB. You may view these documents on the Research and Sponsored Programs web page at [http://research.uwf.edu](http://research.uwf.edu). You acknowledge completion of the IRB ethical training requirements for researchers as attested in the IRB application.

* You will ensure that legally effective informed consent is obtained and documented. If written consent is required, the consent form must be signed by the participant or the participant's legally authorized representative. A copy is to be given to the person signing the form and a copy kept for your file.

* You will promptly report any proposed changes in previously approved human participant research activities to Research and Sponsored Programs. The proposed changes will not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the participants.

* You are responsible for reporting progress of approved research to Research and Sponsored Programs at the end of the project period 09-30-2018. If the data phase of your project continues beyond the approved end date, you must receive an extension approval from the IRB.

* If using electronic communication for your study, you will first obtain approval from the authority listed on the following web page: [http://uwf.edu/offices/marketing/resources/broadcast-distribution-standards/](http://uwf.edu/offices/marketing/resources/broadcast-distribution-standards/).

Good luck in your research endeavors. If you have any questions or need assistance, please contact Research and Sponsored Programs at 850-474-2824 or 850-474-2609 or irb@uwf.edu.

Sincerely,

Dr. Mark Rolsch, Assistant Vice President for Research and Director of the Office of Research and Sponsored Programs

Dr. Ludmila Cesoio-Lima, Chair, IRB for Human Research Participant Protection
Appendix C: Participant Recruitment E-mail
Hello! My name is Corey Nagle. I am a secondary science teacher and am pursuing a
doctorate degree at the University of West Florida. As part of my course requirements, I am
completing a research study on disciplinary literacy instruction in science classrooms. I am
inviting you to participate in the study. Your participation would include allowing me to observe
you teaching science lessons and to interview you on your thoughts about planning,
implementing, and reflecting on science and literacy instruction. If you are willing to participate
in the study, I would welcome the opportunity to meet with you to provide you more details
about the study and participation in the study. I can be reached via e-mail at
cen11@students.uwf.edu or by telephone at (860) 690-0437.

Thank you,

Corey Nagle
Appendix D: Consent Forms
Consent Form

**Title of Research:** A multiple case study of disciplinary literacy instruction in secondary science classrooms

**Researcher:** Corey Nagle

You are being asked to participate in research. For you to be able to decide whether you want to participate in this project, you should understand what the project is about, as well as the possible risks and benefits in order to make an informed decision. This process is known as informed consent. This form describes the purpose, procedures, possible benefits, and risks. It also explains how your personal information will be used and protected. Once you have read this form and your questions about the study are answered, you will be asked to sign it. This will allow your participation in this study. You should receive a copy of this document to take with you.

**Explanation of the Study**

This study is being done to better understand the knowledge and practices that teachers have and apply in teaching disciplinary literacy in science classes.

If you agree to participate, you will be asked to allow the researcher to observe you teaching lessons. You will also be asked to participate in interviews about your planning, implementation, and reflection on lessons about science and disciplinary literacy instruction.

You should not participate in this study if you are unwilling or unable to be observed or are unwilling or unable to participate in interviews.

Your participation will last approximately four months.

**Risks and Discomforts**

No risks or discomforts are anticipated.
Benefits

This study is important to science and society because it will describe ways that teachers incorporate disciplinary literacy teaching in science instruction.

Confidentiality and Records

Information you generate in support of this study will be kept confidential. All notes will be kept in locked filing cabinets. Digital files will be secured on a password protected drive that will only be accessed by the researcher.

Compensation

Participants will not be compensated.

Contact Information

If you have any questions regarding this study, please contact Corey Nagle at cen11@students.uwf.edu or (860) 589-1574 or Dr. John Pecore, Committee Chairperson, at jpecore@uwf.edu or (850) 474-2303.

If you have any questions regarding your rights as a research participant, please contact,
Institutional Review Board University of West Florida, (850) 474-2824,

______________________________________________________________

By signing below, you are agreeing that:

- you have read this consent form (or it has been read to you) and have been given the opportunity to ask questions and have them answered
- you have been informed of potential risks and they have been explained to your satisfaction
• you understand University of West Florida has no funds set aside for any injuries you might receive as a result of participating in this study

• you are 18 years of age or older

• your participation in this research is completely voluntary

• you may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you and you will not lose any benefits to which you are otherwise entitled.

Signature: _________________________________ Date: ________________

Printed Name: ________________________________
Recorded Media Consent
Institutional Review Board
The University of West Florida

Recorded Media Addendum to Informed Consent

For use with general informed consent documents for studies that involve audio, video, photographic, or any other recording (hereafter referred to as recording) of research subjects.

Project Title: A multiple case study of disciplinary literacy instruction in secondary science classrooms

Date: ______________________

Investigator: Corey Nagle
Email Address: cen11@students.uwf.edu
Phone: (860) 589-1574

Description and Purpose of Recording:
The researchers would also like to make video or audio recordings of your interview session in order to aid in the collection of data. The video or audio recordings will not be disseminated to anyone and will be accessed only by the researcher in the compilation of transcripts and notes.

Confidentiality:
All materials will be secured on a password protected drive accessible only to the researcher. Transcription of materials will omit identifying information as to maintain your anonymity. Recordings will be deleted at the conclusion of the study in May of 2018.

Voluntary Consent:
By signing below, you are granting to the researchers the right to use your likeness, image, appearance, and performance – whether recorded on or transferred to videotape, film, slides, photographs, or other media – for preserving, presenting or publishing this research. No use of recorded media will be made other than for the reasons stated herein.

Your participation is voluntary and your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation and withdraw this consent at any time without penalty or loss of benefits to which you are otherwise entitled.

If you have any questions, please contact:
Corey Nagle at cen11@students.uwf.edu or at (860) 589-1574
or
University of West Florida Institutional Review Board
Subject's Printed Name & Signature | Date
---|---
Investigator’s Printed Name & Signature | Date
Appendix E: Semi-Structured Interview Questions Protocol
<table>
<thead>
<tr>
<th>Questions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Teaching Experience and Background Questions</strong></td>
<td></td>
</tr>
<tr>
<td>Can you tell me about your understanding of and training related to literacy instruction in science?</td>
<td></td>
</tr>
<tr>
<td>How do you currently teach science and literacy skills in your classroom? What has influenced these approaches?</td>
<td></td>
</tr>
<tr>
<td>How would you define science and literacy teaching?</td>
<td></td>
</tr>
<tr>
<td>How do you think teaching should be structured to support student development of science and literacy skills?</td>
<td></td>
</tr>
<tr>
<td><strong>General Pedagogy Questions</strong></td>
<td></td>
</tr>
<tr>
<td>Considering instructional shifts required by science curricular revisions and standards and your understanding of science content, skill, and literacy standards, how do you approach instruction planning, implementation, and assessment? What pedagogy, skills, or strategies do you draw from or utilize? Why?</td>
<td></td>
</tr>
<tr>
<td>Considering your experience on teaching literacy in science, how would you describe your approach to teaching science and literacy?</td>
<td></td>
</tr>
<tr>
<td>How do you plan for and then address student challenges in applying literacy and science skills?</td>
<td></td>
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<tr>
<td>How do you assess student science and literacy skills?</td>
<td></td>
</tr>
<tr>
<td><strong>Interview paired with Observation</strong></td>
<td></td>
</tr>
<tr>
<td>Can you please give me an overview of the lesson I will be observing? What literacy and science skills and content will you be teaching? How do you plan on teaching these ideas?</td>
<td></td>
</tr>
<tr>
<td>How do you plan to support or scaffold student learning of literacy and science skill and content? What influenced these decisions?</td>
<td></td>
</tr>
<tr>
<td>How did you consider science and literacy skill development in your lesson planning?</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>How will you assess student understanding of literacy and science skills and content?</td>
<td></td>
</tr>
<tr>
<td><strong>After Observation</strong></td>
<td></td>
</tr>
<tr>
<td>How did you incorporate (insert reading, writing, speaking and listening) in the lesson? How did you incorporate (insert science or engineering practice) in the lesson?</td>
<td></td>
</tr>
<tr>
<td>How did (describe critical incident) influence instruction? What guided your decision making about or response to this event?</td>
<td></td>
</tr>
<tr>
<td>How did you incorporate literacy and science skill and content into the observed lesson? Did your instruction differ from the original plan? How? Why?</td>
<td></td>
</tr>
<tr>
<td>Did you change anything when teaching this lesson to other class periods? Why or why not? How did your instruction change?</td>
<td></td>
</tr>
</tbody>
</table>

Note: Park et al. (2011) formed the foundations for the interview protocol.
Appendix F: Permission to Adapt and Use Interview Protocol
Request Permission for Use of Interview Questions

Corey Nagle <cn111@students.uwf.edu>

To: Soohye Park

Subject: Permission Request

Date: 10:23 AM (45 minutes ago)

Dear Soohye,

My name is Corey Nagle and I am a doctoral student at the University of West Florida in Pensacola, FL. I am in the dissertation phase of my program and am exploring science teachers’ PCK for disciplinary literacy. I am requesting your permission to modify the interview questions protocol from your study cited below for my research and to publish the modified protocol in my dissertation. I will cite your work and credit your work as the foundation of my protocol questions. I have included a draft of the modified protocol for your review.

Thank you for your time and attention to this request.

Sincerely,

Corey Nagle

Study


Draft of modified protocol (attached).

Soohye Park

To me

Date: 11:04 AM (4 minutes ago)

Hi Corey,

Your study sounds very interesting to me. Please feel free to use or modify the questions.

Good luck with your study!
Appendix G: Observation Protocol
### Observation of Disciplinary Literacy Instruction in the Science Classroom

<table>
<thead>
<tr>
<th>Time</th>
<th>Literacy Codes</th>
<th>Practices Codes</th>
<th>Teacher Action</th>
<th>Critical Incident(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st 10 min.</td>
<td>□ SC: KN SK</td>
<td>QP MD</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ RD: CA DL</td>
<td>IV DA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ WR: CA DL</td>
<td>MCT ES</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ SL: CA DL</td>
<td>AE INFO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd 10 min.</td>
<td>□ SC: KN SK</td>
<td>QP MD</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ RD: CA DL</td>
<td>IV DA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ WR: CA DL</td>
<td>MCT ES</td>
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<tr>
<td></td>
<td>□ SL: CA DL</td>
<td>AE INFO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd 10 min.</td>
<td>□ SC: KN SK</td>
<td>QP MD</td>
<td></td>
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<td></td>
<td>□ RD: CA DL</td>
<td>IV DA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ WR: CA DL</td>
<td>MCT ES</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ SL: CA DL</td>
<td>AE INFO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th 10 min.</td>
<td>□ SC: KN SK</td>
<td>QP MD</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>□ RD: CA DL</td>
<td>IV DA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ WR: CA DL</td>
<td>MCT ES</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ SL: CA DL</td>
<td>AE INFO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th 10 min.</td>
<td>□ SC: KN SK</td>
<td>QP MD</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>□ RD: CA DL</td>
<td>IV DA</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>□ WR: CA DL</td>
<td>MCT ES</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>□ SL: CA DL</td>
<td>AE INFO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6th 10 min.</td>
<td>□ SC: KN SK</td>
<td>QP MD</td>
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<tr>
<td></td>
<td>□ RD: CA DL</td>
<td>IV DA</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>□ WR: CA DL</td>
<td>MCT ES</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>□ SL: CA DL</td>
<td>AE INFO</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations:
- SC: Science Content; RD: Reading; WR: Writing; SL: Speaking and Listening; KN: Knowledge; SK: Skill; CA: Content Area; DL: Disciplinary Literacy; QP: Questioning/Identifying Problems; MD: Modeling; IV: Investigating; DA: Data Analysis; MCT: Mathematical/Computational Thinking; ES: Explaining Solutions; AE: Arguing from Evidence; INFO: Obtaining, Evaluating, and Communicating Information

Classroom Set-Up:
Appendix H: Document Review Protocol
<table>
<thead>
<tr>
<th>Important Components of Disciplinary Literacy Instruction in Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science (content &amp; skills)</td>
</tr>
<tr>
<td>What learning is expected based on the document?</td>
</tr>
<tr>
<td>How will learning opportunities be structured??</td>
</tr>
<tr>
<td>What evidence of teacher knowledge of content and pedagogy are presented in the document?</td>
</tr>
<tr>
<td>How are the educator actions in this document aligned with disciplinary literacy instruction? Are there connections to content area literacy instruction?</td>
</tr>
<tr>
<td>What application of skill or content is expected to take place based on educator actions in this document?</td>
</tr>
<tr>
<td>What educator actions are presented in the document or demonstrated through the development of the document?</td>
</tr>
<tr>
<td>Question</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>What evidence of assessment is presented in the document?</td>
</tr>
<tr>
<td>How will the document be used by the educator in instruction?</td>
</tr>
</tbody>
</table>
Appendix I: Permission to Use Figure
Dear Corey Nagle,

Thank you for your request. You can consider this email as permission to use the material as detailed below in your upcoming dissertation. Please note that this permission does not cover any 3rd party material that may be found within the work. You must properly credit the original source, *Qualitative Data Analysis: A Methods Sourcebook*. Please contact us for any further usage of the material, or if you should have any additional questions.

Best regards,

**Craig Myles**  
*Rights Coordinator*  
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USA

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Best regards,

Michelle Binur

*Contract Administrator*  
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Thousand Oaks, CA 91320  
USA

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Singapore | Washington DC
To Whom It May Concern:

I am a doctoral student at the University of West Florida writing my dissertation tentatively titled *A Multiple Case Study: Disciplinary Literacy Instruction in Middle Level Science Classrooms* under the direction of my dissertation committee chaired by Dr. John Pecore.

I am in the dissertation phase of my program and am requesting your permission to reproduce Display 1.1 from page 14 in *Qualitative Data Analysis: A Methods Sourcebook (3rd Edition)* by Miles, Huberman, and Saldaña.

Specifically, I am requesting to reproduce:

I am requesting written permission to reproduce the display in my dissertation. If you do not control these rights in their entirety, please inform me of the proper agency to contact.

I may be contacted via the following:
Corey Nagle
91 South Street Ext.
Bristol, CT 06010
(860) 589-1574
cen11@students.uwf.edu

Thank you for your time and consideration of my request.

Sincerely,
Corey Nagle
Appendix J: Proposed Time Schedule for Study
The proposed time schedule for the study is as follows:

June – August 2017: Writing and defense of proposal

August-September 2017: Institutional Review Board application and approval

September/October 2017: Recruit participants and obtain informed consent.

October – January 2018: Data collection and analysis.

January – May 2018: Data analysis and completion of results and conclusions of study.

January – May 2018: Member checking and Additional data collection as warranted by analysis.

May – June 2018: Completion of final chapters.