CROSSING BORDERS: HIGH SCHOOL SCIENCE TEACHERS LEARNING TO TEACH THE SPECIALIZED LANGUAGE OF SCIENCE

By

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To my husband and best friend, Rob

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The highly specialized language of science is both challenging and alienating to adolescent readers. This study investigated how secondary science teachers learn to teach the specialized language of science in their classrooms. Three research questions guided this study: (a) what do science teachers know about teaching reading in science? (b) what understanding about the unique language demands of science reading do they construct through professional development? and (c) how do they integrate what they have learned about these specialized features of science language into their teaching practices?

This study investigated the experience of seven secondary science teachers as they participated in a professional development program designed to teach them about the specialized language of science. Data sources included participant interviews, audio-taped professional development sessions, field notes from classroom observations, and a prior knowledge survey.

Results from this study suggest that science teachers (a) were excited to learn about disciplinary reading practices, (b) developed an emergent awareness of the

specialized features of science language and the various genres of science writing, and (c) recognized that the challenges of science reading goes beyond vocabulary. These teachers' efforts to understand and address the language of science in their teaching practices were undermined by their lack of basic knowledge of grammar, availability of time and resources, their prior knowledge and experiences, existing curriculum, and school structure.

This study contributes to our understanding of how secondary science teachers learn about disciplinary literacy and apply that knowledge in their classroom instruction. It has important implications for literacy educators and science educators who are interested in using language and literacy practices in the service of science teaching and learning.

CHAPTER 1
INTRODUCTION

Background

There is widespread recognition that a focus on adolescent literacy is both important and necessary (Biancarosa & Snow, 2004; Heller & Greenleaf, 2007; Moje & Young, 2000; National Council of Teacher of English [NCTE], 2004; Vacca, 2002). With fast-paced changes and increasing technological advances, adolescents must have advanced literacy skills to participate competitively in today's society (Heller & Greenleaf, 2007; Moje & Young, 2000). In a position statement on adolescent literacy from the International Reading Association (IRA), Moore, Bean, Birdyshaw, & Rycik (1999) state: "adolescents entering the adult world in the 21st century will read and write more than at any other time in human history" (p.3). Yet reports from the National Assessment of Educational Progress (NAEP) show little improvement in secondary students' reading. Nearly two-thirds of eighth and twelfth grade students are performing below the proficient level of reading (Heller & Greenleaf, 2007, National Center for Educational Statistics [NCES], 2007). This dissonance between how secondary students are performing in reading and the advanced level of reading skills required by society are cause for alarm and warrants greater attention. Secondary students must receive instruction in reading within their content classes in order to meet the literacy demands of current workplace and school environments (Fang & Schleppegrell, 2008; Moje, 2008).

Numerous calls have been issued from researchers and organizations for secondary teachers to address the specific ways that literacy is used in content areas (Biancarosa & Snow, 2004; Heller & Greenleaf, 2007; IRA & NMSA, 2001; Moje, 2008;

Moore, Bean, Birdyshaw, & Rycik, 1999). According to the National Council of Teachers of English (NCTE):

Each academic content area poses its own literacy challenges in terms of vocabulary, concepts, and topics. Accordingly, adolescents in secondary school classes need explicit instruction in the literacies of each discipline as well as the actual content of the course so that they can become successful readers and writers in all subject areas" (NCTE, 2007, p. 2).

The NCTE further notes that the new forms, purposes, and processing demands associated with secondary content area reading require that "teachers show, demonstrate, and make visible to students how literacy operates within the academic disciplines (NCTE Commission on Reading, 2004, p. 3)." In order to do this, teachers must themselves develop an understanding of how language is characteristically used to construct content in their subject areas.

Secondary teachers need to instruct students how to read the content of subject areas like history, science, and math (Biancarosa & Snow, 2004; Heller & Greenleaf, 2007; Schleppegrell, 2004). Scholars (e.g., Fang & Schleppegrell, 2008) suggest that as students move into the secondary school, they encounter texts that deal with more specialized topics and use language that is more complex than those they typically read in the elementary school. The patterns, structures, and grammar of these texts may be unfamiliar to secondary students. In order to engage students with subject area texts, teachers must address not only the content, but the way that language is used within the discipline to communicate information (Shanahan & Shanahan, 2008).

Disciplinary knowledge is primarily transferred through text (Fang & Schleppegrell, 2008). In science for example, scientists use text to gain access to past studies, record and report current results of studies, and write for future generations of scientists (Hand, et al., 2003). In order for students to understand how language is used in specific disciplines, teachers must provide opportunities for students to experience and discuss the language of various texts types so secondary students can begin to see how reading and writing are an integral part of each subject (Shanahan & Shanahan, 2008).

Science Literacy

Science literacy is at the forefront of reform efforts in science education. Both the *National Science Education Standards* (National Research Council [NRC], 1996) and the *Benchmarks for Science Literacy* (The American Association for the Advancement of Science [AAAS], 1990) outline goals for teaching science literacy in K-16 science education. The National Science Teachers Association (NSTA) advocates that science literacy is “a goal that we arguably all share in common” (NSTA, 2000). This focus on science literacy was triggered by reports of students’ performances in science literacy at both the national and international level.

At the national level, The National Assessment of Educational Progress (NAEP) measures student progress in science literacy. According to the most recent NAEP results in 2005, achievement in science literacy is relatively stagnant. While there are improvements in average scores for 4^{th} graders performance, they are only significant in the bottom half of the scale with an increase from 61% to 68% in the number of students performing at or above the *basic* level. However, the number of students performing at or above the *proficient* level shows no significant change. For 8^{th} graders, scores remained unchanged in the 2005 assessment with only 59% of eighth grade students scoring at or above the *basic* level. Finally, the twelfth-grade students' scores significantly declined from 57% scoring at or above the basic level in 1996 to 54% in 2005. (NAEP, 2008, p. 1)

At the international level, student performance from the United States ranges widely. The Trends in International Mathematics and Science Study (TIMSS) reports that even though 4^{th} grade U.S. students performed better than the international average, they are not maintaining the same levels of improvement in science literacy as their international peers. Eighth graders however did show improvement in their science achievement, outperforming 11 countries in 2003 compared to only five countries in 1995 (NCES, 2008, p.1; Gonzales et al., 2004).

Another international assessment reports three-year trends in 15-year olds' performance in science literacy. The Program for International Student Assessment (PISA) results shows that U.S. students performed relatively the same from 2000 to 2003. However, U.S. students performed below the international average with 18 countries outperforming the U.S. (Lemke, et al., 2004). While subtle differences between these test frameworks make direct comparisons difficult, the alarm is just the same- methods of improving students' science literacy in the United States must continue to be explored (Hand, et al., 2003; Shanahan & Shanahan, 2008).

The issue though lies in the complexity of science literacy. Despite the consensus that science literacy is a worthy goal, the concept of science literacy is broadly defined and explained (AAAS, 1993; DeBoer, 2000; NRC, 1996; Wellington & Osborne, 2001). Norris and Phillips (2003) compare many definitions of science literacy, noting the variety of ways that the concept is used: e.g. knowledge of and the ability to recognize science content; knowledge for participation in science based social events, and the ability to use scientific knowledge for problem solving (p. 225). Through their analysis, Norris and Phillips develop their own concept of science literacy, separating the idea into the derived sense, being educated and knowledgeable about science content, and the fundamental sense, being able to read and write science content.

Considering Norris and Phillips' interpretation of science literacy, it becomes necessary for science teachers to go beyond just knowing and transmitting scientific information. Attending to the fundamental side of science literacy requires science educators to be knowledgeable in reading and writing science themselves so that they may teach their students to do the same. Wellington and Osborne (2001) contend that science teachers must "give prominence to the means and modes of representing scientific ideas, and explicitly to the teaching of how to read, how to write, and how to talk science (p. 138). Integrating discipline-specific reading strategies into secondary science teaching will bring attention to the fundamental side of science literacy and provide students with authentic experiences reading, writing, and talking about scientific information. In order for secondary students to achieve high levels of science literacy, they must be able to use reading to analyze, critique, question, and explore all types of scientific information.

In science, reading is particularly challenging for students. Students are more familiar with the structure and language of narrative texts. The language of science texts on the other hand typically serves to classify and explain information (Fang, 2005). Science texts have been described as using language that is simultaneously technical, dense, and abstract (Fang, 2005, 2006; Halliday & Martin, 1993). This highly specialized language used in science is vastly different from the narrative language that is more common in schools and therefore is often alienating to students (Halliday & Martin, 1993; Wellington & Osborne, 2001).

Experts argue that the study of language in science is essential to develop students' science literacy (Fang, 2006; Gee, 2004; Norris & Phillips, 2003; Schleppegrell, 2004; Yore, 2003). Learning science involves not just knowing the subject matter but knowing how to recognize and interpret the unique linguistic features of science language (Fang, 2005; Gee, 2004). Recent scholarship in both reading and science education recommends that to promote science literacy among students, science teachers need to attend to not only the content of science, but also the specialized language features of science in their teaching (Fang, Lamme, & Pringle, 2008; Shanahan & Shanahan, 2008; Wellington & Osborne, 2001).

Because the term "science language" can be interpreted widely by both literacy and science education scholars in various contexts, it is necessary to define what science language means in this study. The concept of science language is used to mean how language is characteristically used by scientists to construct science knowledge. This study embraces the idea that the linguistic features of the language of science are unique and operate functionally to represent the particular ways that scientists communicate scientific information through written mode. Because of my focus on reading, science language as used in this study is concerned primarily with written science texts.

Research Problem

Secondary teachers must consider how language is integral to the learning and doing of science. Knowing the content of science is important and necessary, but it is not enough to be an effective science teacher. Science teachers must also be able to help their students gain access to scientific information through explicit instruction in how the discipline of science uses language to construct knowledge (Fang & Schleppegrell, 2008; Shanahan & Shanahan, 2008). One way to increase students' access is to provide opportunities in science classrooms for students to practice reading various types of scientific information.

Documentation however shows the daily reading practices of secondary teachers are widely varied (Alvermann & Moore, 1990). In many classrooms, reading serves a supportive role, with the teacher serving as the main source of information through lecturing and giving notes. Reading is more often assigned than taught. In addition, the major source of reading at the secondary level is the textbook and the reading is typically centered on locating factual information in the textbook to answer specific questions versus reading for understanding (Alvermann & Moore, 1990; Yore, 1991).

Another problem with reading in secondary schools is teacher support. Secondary teachers report that professional development that addresses reading in the content area is too general and information is given too quickly (Muth, 1993; Vigil & Dick, 1997). Teachers are often given a few examples of reading strategies in a workshop and then expected to integrate it on their own into their teaching practice.   Secondary teachers then view reading as something to do *in addition* to their already tight curriculum plans. (Allington, 2002; Bintz, 1997; Hagar & Gable, 1993; Konopak & Readance, 1994, Sturtevant, 1996).

It is critical that science teachers are convinced of the value of teaching students how to read the specialized discourse of science. When students leave high school, much of their exposure to scientific information will occur through written text. Students must gain access to the particulars of science language while in school in order to independently evaluate and criticize scientific information presented to them as adults (Wellington & Osborne, 2001).

Support for implementing discipline-specific reading strategies into core subject areas at the secondary level is building (Heller & Greenleaf, 2007; Norris & Phillips, 2003; Fang & Schleppegrell, 2008; Moje, 2008; Shanahan & Shanahan, 2008; Siebert & Draper, 2008), but the empirical research in this area is lacking. Unfortunately, research on the effectiveness of explicit instruction on science linguistic devices in educational settings is not available. Hand and Prain (2006) question: “Can the use of approaches [in science education] that are based on using language replicate how scientists use language and promote understanding of science concepts? The research to date is very thin on this question with much work to be done” (p.105). Research in the secondary setting has yet to address if teaching students how to read and write like scientists will improve their comprehension and lead to greater independence in science learning.

Most of the empirical research that does exist at the secondary level with reading in the content area focuses on integrating generalizable reading skills and strategies into the curriculum (e.g., phonics, fluency, cognitive/metacognitive strategies) without attending to the discipline-specific language demands of content reading (Kamil & Bernhardt, 2004; Sawchuk, 2006). Although these skills and strategies are valuable and necessary, reading demands in areas such as science, math, and history are unique. It has been argued that the content areas require that teachers explicitly teach students how to read those texts (Fang & Schleppegrell, 2008; Heller & Greenleaf, 2007; Moje, 2008; Shanahan & Shanahan, 2008).

It is important to study the role of language in learning to read science texts. This study goes beyond the traditional conceptions of reading infusion in content areas and explores how teachers come to understand the unique linguistic features of science texts and apply that knowledge to their teaching practice. This study will attempt to help science teachers understand how the study of language is central to the teaching of science and how explicit teaching of the language features could contribute to students' reading comprehension of scientific information.

Significance

This research is significant because it addresses numerous calls from researchers and organizations for secondary teachers to address the specific ways that literacy is used in content areas (Biancarosa & Snow, 2004; IRA & NMSA, 2001; Moore, Bean, Birdyshaw, & Rycik, 1999, Heller & Greenleaf, 2007). If teachers understand how language works in science, they can better instruct their students in how to comprehend challenging science texts and use language effectively to communicate scientific principles and understanding when writing and talking about science.

This research is also significant in that it addresses the concern of secondary teachers that professional development in secondary reading instruction is not content specific. This study addresses the discipline-specific reading demands of science. Science teachers will be engaged in learning about the specialized features of science language and applying what they learn to teaching students how to comprehend science texts.

This study goes beyond the teaching of generalized reading strategies (e.g., think aloud, KWL, graphic organizer) in science curriculums. It is valuable to science teacher education because it investigates how teachers learn to teach the specialized language of science through reading instruction. As more research is conducted on the specialized language of science, better programs can be developed to train teachers in how to teach students about the language of science. This research will contribute to the science education community's knowledge about the role of language in teaching science by showing how these secondary science teachers integrate their understanding of the role of language in learning how to comprehend science text.

Purpose of the Study

The purpose of this study is to enhance secondary science teachers' expertise in reading instruction. Recent scholarship in both reading and science education recommends that to promote science literacy among students science teachers need to attend to not only the content of science but also the specialized features of science language in their teaching (Fang, Lamme, & Pringle, 2008; Wellington & Osborne, 2001). Through professional development and classroom observations, this study will document how science teachers learn about specialized features of science language and integrate that knowledge into their science teaching.

Research Question

Scholars contend that secondary content teachers should understand how language works to develop knowledge in their content area in order to effectively teach their students how to read the particular content (Fang & Shleppegrell, 2008; Moje, 2008; Shanahan & Shanahan, 2008). This study examines how secondary science teachers learn about the specialized features of science language. Therefore, the overarching research question guiding this study is: How do secondary science teachers learn about the specialized language of science and apply it to teaching reading of scientific texts? The following sub-questions are addressed in the study:

(1) What do science teachers know about teaching reading in science?

(2) What understanding about the specialized features of science language do they construct through professional development?

(3) How do they integrate what they have learned about these specialized features of science language into their teaching practices?

This study will involve engaging seven secondary science teachers in ongoing professional development sessions focused on learning about the specialized discourse of science. Through shared readings, discussions, and co-planning with peers and the researcher, these teachers will consider how explicitly teaching students about science language could impact their teaching practice and student learning. Initial meetings will introduce the topic of the language of science and provide professional reading materials that recommend that content teachers attend to the discipline-specific reading needs of the subject areas. Subsequent meetings will address the specific ways that science manipulates language to construct scientific knowledge and information, as well as strategies that teachers can use to develop students' awareness of and insights into the language of science. Between professional development sessions, I will participate in the individual teachers' classrooms as an observer. The purpose of these classroom visits is to observe how and if classroom teachers address the specialized language of science in their daily practice and to record what strategies and ideas they use from professional development meetings.

Study Delimitations and Limitations

There are delimitations related to the potential findings of this research. First of all, the focus of the professional development on discipline-specific reading strategies in science could be applied to other content areas at the secondary level. Professional development for history, math, or English teachers could be modeled after the plan for professional development used in this study. In addition, while this study is directed towards practicing teachers, the information could be adapted and used with prospective teachers in teacher education programs. The results of this study could inform teacher educators in how to train beginning teachers to integrate discipline-specific reading instruction into their content teaching.

There are also potential limitations of this research. Because only seven teachers participated in this study, it is difficult to generalize their experience to all secondary science teachers. Each participant brought their own experiences and views to the study setting and learning process. It will be up to the reader of the research to decide how the participants' experiences may be useful or applicable to a new setting. Additionally, the setting of the school and the community is particular to this study. Again, readers will need to determine if appropriate comparisons can be drawn between settings. Another limitation is my goal for the participants in this research. My intention for conducting this study is to help secondary science teachers integrate the teaching of the specialized language of science into their daily classroom practice. Therefore, I was actively involved with the teachers' learning process, not just silently watching and observing.

CHAPTER 2
LITERATURE REVIEW

The purpose of this study is to explore how secondary science teachers learn to teach science as a specialized language in their own classrooms. Recent scholarship in both reading and science education recommends that science teachers attend to not only the content of science in teaching but the way that language is used in science as well (Fang, Lamme, & Pringle, 2008; Wellington & Osborne, 2001). This chapter presents relevant research related to teaching the specialized language features of science.

The issue of science literacy has pervaded the science education community. Debate over what it means to be scientifically literate has prompted many scholars to offer definitions and explanations of the concept. Therefore, the first topic addressed is the meaning of science literacy. A review of what professional organizations and scholars are saying about what is means to be scientifically literate contributes to an understanding of the big picture of what is happening in science education.

The next topic covered is the relevance of reading in science including current research on reading-science integration. It is important to understand how reading plays a role in science learning in order to develop and plan strategies to improve student learning. Looking closely at what has already been done in this area will inform the organization and planning of this study.

Specifically, since this study is interested in how teachers learn about the specialized language of science, a review of what scholars are saying about the importance of teaching about the features of science language is necessary. Within this review, the specialized features of science language will be identified and discussed.

This review will conclude with a discussion of science teachers' beliefs and attitudes about reading integration and teacher learning and professional development. Because this study includes planning professional development for secondary science teachers, the studies in this section inform the design and implementation procedures of the professional development.

Science Literacy

In its most basic sense, science literacy means being able to read and write science (Wellington & Osborne, 2001). However, google the words "science literacy" and a multitude of sites show up offering various explanations of the concept. Whereas some place emphasis in science literacy on being able to read everyday newspaper articles about science related issues, others emphasize that science literacy involves a deeper understanding of the vocabulary and nature of scientific information (Gee, 2004; Wellington & Osborne, 2001). While it is generally agreed upon that being scientifically literate is important and desirable, various interpretations of how to develop scientific literacy have been offered by members of the science community. This discussion of science literacy is going to focus on explanations of science literacy that have been presented in direct relationship to K-12 science education.

The American Association for the Advancement of Science (AAAS) brought national attention to the issue of science literacy with the release of Project 2061 in 1989, a long term initiative to promote literacy in science, math, and technology. AAAS (1989) calls for "science for all Americans" and broadly defines the concept of science literacy as follows:

Science literacy, which encompasses mathematics and technology as well as the natural and social sciences, has many facets. These include being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes. (Introduction section, para. 21). This broad encompassing definition led the way to the AAAS' next publication of the Benchmarks for Science Literacy, a set of goals to guide educators in how to develop students' science literacy at each grade level.

As national attention in education was drawn to science literacy, the National Research Council (NRC) then released the National Science Education Standards in 1995, supporting calls for science literacy for all and offering yet another interpretation of science literacy:

Scientific literacy means a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (NRC, 1995, chap. 2).

Even further, the National Science Teachers Association (NSTA) advocates strongly for science literacy in their position statement, *Beyond 2000—Teachers of Science Speak Out (2003)*, "As we enter the 21st century, NSTA reaffirms the importance of scientific literacy for ALL students" (p. 1). In this document, NSTA supports both the Benchmarks for Science Literacy and The National Education Standards as worthy goals for helping science teachers to increase the science literacy of all students.

These national organizations have forced the science education community to reconsider the relationship between science and literacy. As evidenced by recent international conferences in science education (Hand, Alvermann, Gee, Guzzetti, Norris, Phillips, Prain, & Yore, 2003; Saul, 2004) and several prominent publications (e.g. Norris & Phillips, 2003, Wellington & Osborne, 2001), this issue of integrating literacy and science has gained much attention in the field of science education. Many researchers and science educators have described and identified what they believe are key features of scientific literacy (DeBoeur, 2000; Hand & Prain, 2006; Fang, 2006; Norris & Phillips, 2003; Yore, Bisanz, & Hand, 2003; Yore & Treagust, 2006).

One of the most substantial and highly referenced explanations of science literacy is offered by Norris and Phillips (2003). They assert that reading and writing are essential elements of science. Being scientifically literate involves not just knowing facts and information about science, but being able to use reading and writing to learn science. Norris and Phillips separate this knowledge of science into *the derived sense*, knowing the content and information of science, and the fundamental sense, being able to write and read in science. So not only should science education focus on teaching about science, but it also must encompass how to do science. Wellington & Osborne (2001) support this notion, arguing that in order to foster students' science literacy, science educators must explicitly teach "how to read, how to write, and how to talk science" (p. 138). If the purpose of science education then is to generate students who can read, write, and talk science then a central consideration in promoting science literacy must involve a consideration of the role of language in science.

The idea that teaching students to become scientifically literate must involve direct instruction in learning the language of science has received support throughout the science education community (Fang, 2005, 2006; Lemke, 1990; Yore, Bisanz, & Hand, 2003; Wellington & Osborne, 2001). Halliday & Martin (1993) contend that science is often alienating to students because the distinctive features of scientific language are so divergent from students' everyday language. In order to foster science literacy, students must engage in behaving like scientists, using science language to evaluate, critique, and consider varying scientific ideas (Fang, 2005, 2006; Gee, 2004; Halliday & Martin, 1993; Schleppegrell, 2004). The varying views of science literacy agree that students must know not only science facts but be able to use language to think more deeply about scientific issues and ideas.

This consideration of science and literacy in the field of science education runs parallel to calls in literacy education for changes in how literacy is addressed in the content areas such as science, history, and math. The Reading Next Report (2004), contends that, "the idea is not that content-area teachers should become reading and writing teachers, but rather that they should emphasize the reading and writing practices that are specific to their subjects, so students are encouraged to read and write like historians, scientists, mathematicians, and other subject-area experts (Biancarosa & Snow, p. 15). Incorporating literacy instruction into the content areas is widely supported by literacy experts and national organizations (National Council of Teachers of English, 2007; National Middle School Association, 2001; Moore, Bean, Birdyshaw, & Rycik, 1999; Vacca, 2002).

The notion of science literacy as it relates to K-12 education is quite complex yet the various explanations and discussions offered by professionals in both the field of science and the field of literacy support the notion that in order to foster science literacy in schools, it is both important and necessary to consider how language activities play a role in the learning and doing of science. A new vision for science education calls for both "hands-on" and "minds-on" learning (Hand et al., 2003). The addition of the "minds-on" part addresses the need for students to be involved in reading, writing, and thinking deeply about science concepts. This change in emphasis encourages teachers to provide opportunities for students to behave like scientists, engaging in authentic science related reading and writing experiences. In order to develop the science literacy of students, attention must be shifted in science education to include both "hands on" and "minds-on" experiences. According to Hand & Prain (2006), "We need to come to some understanding of how we can engage students in classroom environments that move past replication (knowledge reproduction) to intelligent habits in order to encourage them to act like 'real scientists' (knowledge production)" (p. 106). The role of literacy in science education must be reconceptualized.

The Relevance of Reading in Science

"When pupils leave school they are far more likely to read about science than they are to ever do it. . . . The ability to read about science carefully, critically and with a healthy skepticism is a key element of scientific literacy. Moreover, it is a prerequisite of citizenship and playing a part in a democracy" (Wellington & Osborne, 2001, p. 42).

The role of text in learning science has been widely visited by scholars (Hand et al. 2003; Lemke, 2004; Norris & Phillips, 2003). Text serves the purpose in science communities of transmitting ideas, theories, and arguments between scientists. Therefore, the ability to read text in science becomes essential if one is to understand scientific information. Norris and Phillips (2003) describe this relationship between reading and science as constitutive, wherein without text and reading, the essence of science would not exist. Hand et al. (2003) further elaborate on the role of reading in science:

Without text and without reading, the social practices that make science possible could not be engaged: recording and preserving data; encoding accepted science for anybody's use, reviewing of ideas by scientists anywhere; reexamining ideas at any point in time; connecting ideas to those developed previously (intertextuality); communicating ideas between those who have not met or lived at the same time; encoding variant positions; and focusing attention on a text for the purpose of interpretation, prediction, explanation, or test. (p.612)

In their review of language arts and science research, Yore, Bisanz, and Hand (2003) identify that the current trend in viewing reading in science is interactive in nature (p.705). Meaning is constructed through the interaction between the text, the reader, and the socio-cultural context. A traditional view of reading places the role of the text as authoritative and the role of the reader to simply locate and recall information in the text. In contrast, a constructivist view of reading positions reading as an active process in which the three components – the reader, the text, and the socio-cultural context- intertwine to create unique interpretations and understandings of written materials.

This constructivist view of reading is supported by both literacy (Bruner, 1986) and science experts (Norris & Phillips, 2003). Louise Rosenblatt (1969) triggered this notion of reading as transactional, describing the relationship between the reader and the text as active, in which neither the text nor the reader are supreme in the relationship. During the reading process, the reader brings prior knowledge, experience, and ideas and to the interpretation of the words in the text. So each interaction between text and reader is unique. Recent scholarship in literacy includes the importance of the socio-cultural context on the reading process, acknowledging the influence of the characteristics of the environment in which the information is being read (Bean, 2000; Moje, Dillon, & O'Brien, 2000; Moje & Young, 2000; Pardo, 2004; Ruddell & Unrau, 1994; Vacca, 2002). The unique aspects of individual classrooms – such as teacher directions, classroom organization, and community values- interact with the transaction between the reader and the text to create meanings that are unique to that time and place.

Viewing reading as a constructive process then supports Norris and Phillips' (2003) notion of a fundamental sense of science literacy. In science, reading requires the reader to think about previous encounters with the same topic, to make judgments about the validity of the author's arguments, to apply appropriate reading strategies, to consider what other texts have said about the topic, to question, and to synthesize the new information in order to create meaning (Yore, 2004). If the aim of science education is to replicate the way real scientists behave, then science teachers must engage students in reading (Wellington & Osborne, 2001, p. 42).

Implications from this standpoint for the science classroom are wide. Immersing students in authentic science reading tasks can develop and advance science literacy. Scientific information is primarily shared with the general public through texts like newspapers, magazines, and the Internet. Therefore, students need extended opportunities in classrooms to engage in reading real science information from a variety of scientific resources. Students must develop the ability to understand, analyze, and make judgments about the scientific information being read. Fostering this interaction with various texts encourages students to grapple with major scientific concepts and ideas; reading becomes a means to thinking critically and constructively about science.

Unfortunately, active reading is often neglected in the science classroom (Palinscar & Magnusson, 2001; Wellington & Osborne, 2001). Reading in science is often isolated to looking up information in a textbook to answer questions or learning specialized vocabulary (Yager, 2004). In an informal survey, Guzetti, Hynd, Skeels, and Williams (1995) report that two-thirds to three-fourths of high school students never or rarely use textbooks beyond completing the assigned problems. Further, many students avoid reading in science because they find it challenging and alienating (Lemke, 1990; Wellington & Osborne, 2001).

In thinking about science and reading, it is important to consider how the language of science is distinctive from the everyday language that students use. Gee (2004) argues for teaching students the academic language of science. Scientists have particular ways of using language to convey meaning. The language choices of scientists- including vocabulary and grammar- construct knowledge in science. Making students aware of how scientists use language in science will enhance reading comprehension of scientific information (Fang, 2006; Gee, 2004).

Research on the Integration of Science and Reading

While describing a middle school science classroom where the teacher attends to reading in science, Topping and McManus (2002) report that, "Students in this class not only become interested in reading science, but they also learn how (p. 32)." While many anecdotal accounts support the value of implementing reading in content areas (Creech & Hale, 2006), the empirical literature base on this topic is scant with most of the studies occurring at the elementary level.

One of the first studies to show support for integrating reading and science was conducted in an elementary setting with third grade students. Morrow, Pressley, Smith, & Smith (1997) found that students who received language arts and literature-based instruction with science instruction outperformed students who did not receive the literature-based instruction. During instruction, students receiving the treatment were immersed in literacy activities like independent reading and writing, literacy centers, and teacher-modeled lessons. The treatment group also read children's literature related to the science concepts being read about in their science textbooks. The combination of the traditional explicit instruction from the textbooks with the literature-based instruction proved to be successful with those students who received the treatment scoring significantly higher on all literacy measures and two out of three science measures.

In a similar study, Guthrie et al (1998) investigated the effectiveness of integrating science and literacy goals with third and fifth grade students. The CORI framework

(Concept-Oriented Reading Instruction) combined the use of motivational strategies, reading strategies, and science-related trade books (Guthrie, et al., 1998; Guthrie, Wigfield, & Perencevich, 2004). Students involved with CORI received explicit instruction of reading strategies within a thematic science unit. Strategies taught included using prior knowledge, searching for information, comprehending informational text, interpreting literary text, and self- monitoring. Compared with students in a traditional basal centered program, Guthrie and colleagues found that students who were in the experimental groups showed positive gains. Students who received CORI were more likely to use multiple strategies when learning from texts. In addition, students who were proficient in their strategy use demonstrated gained higher levels of conceptual knowledge. Finally, researchers found that the instructional conditions of CORI had a positive indirect effect on conceptual transfer.

In another study, Romance and Vitale (1992) attained positive results in their investigation of an integrated fourth grade language arts and science program. Students were immersed in a 2-hour time block that involved explicit instruction in reading strategies such as cause-effect relationship, main idea, and questioning, multiple opportunities to read from a variety of materials, and hands-on activities. When compared with peers on standardized tests, students involved with the integrated curriculum performed significantly better.

These studies indicate positive results in students' performance when integrating reading and science at the elementary level. However, questions remain about the effectiveness of integrating reading into secondary curriculums. Generally, the elementary based studies involve integrating science into a flexible schedule and working with teachers who have some training in reading. At the secondary level, teachers are more focused on teaching content and have little knowledge about teaching reading within their content (O'Brien, Stewart, & Moje, 1995). In addition, the structure of secondary schools differs greatly from the elementary setting. Secondary teachers usually see many students for short periods of the day making it challenging to implement new strategies and ideas (Eccles & Harold, 1993).

Recently, two studies conducted in middle school settings emerged reflecting the same positive results from the integration of reading and science as discovered in the elementary research. A study conducted in a middle school setting found positive results from infusing reading instruction into the science curriculum (Fang et al., 2008). Over a year long period, science teachers and university personnel provided weekly reading strategy lessons in the middle school classroom along with a home reading program. Students who received the reading infusion program outperformed students on a measure of science literacy over those who did not participate in the integrated curriculum.

Another study also achieved positive results from integrating reading and writing into the science curriculum (Gaskins et al., 1994). Researchers merged reading and writing into the science curriculum of a middle school that serves students with below-average reading scores. Teachers explicitly taught reading, writing, and thinking strategies to help students solve science problems. Strategies included asking questions, making predictions, comparing and contrasting information, reading from a variety of sources, and note-taking. Teacher interviews further provided support for the concept with teachers reporting higher levels of student engagement and more effective instruction through use of the process model. A performance based assessment served as a pre-and post test measure. Researchers found that the impact of the integrated curriculum had positive effects on student learning.

At both the elementary and the middle level setting, students showed positive gains from participating in integrated science and reading instruction. Providing opportunities for extended time for reading from various types of scientific texts and teaching explicit reading strategies appear to be useful methods for blending reading into science classrooms. However, the studies focus on generalizable reading strategies (e.g. prior knowledge, concept mapping, self monitoring, etc.) and are mostly integrated within a flexible program with an emphasis on language arts instruction also. It appears that none of the studies consider how the language of science impacts students' comprehension of challenging science materials. Studies investigating the impact of using language-based activities to support students understanding of the academic language of science are still needed.

The theoretical debate about how to provide instruction that supports students' acquisition of academic languages is withstanding, yet there is a dearth of empirical studies in this area. It has been well-established that the language of science is unique and complex (Gee, 2004; Halliday & Martin, 1993) and students are having trouble with comprehension of science texts. It is possible that students' lack of understanding of science language could contribute to their difficulties with understanding science texts. Therefore, there remains a need to discover the best methods for teaching students how to acquire and use this language effectively in order to improve their comprehension of these demanding texts.

A few studies look at language-based activities in content learning. Studies show that explicit teaching of text structure awareness does positively impact students' understanding of content (Cook & Mayer, 1988; Richgels, McGee, Lomax, & Sheard, 1987; Spiegel & Barufaldi, 1994). Further investigations have considered how talking and writing can enhance content learning (Rivard, 2003; Rivard & Straw 2000). Rivard (2003) confirms that involving students in language-based activities in science classrooms such as peer discussion and written explanations improves learning of content material.

Recently, Purcell- Gates, Duke, & Martineau (2007) conducted a longitudinal study to explore the impact of authentic reading and writing experiences and explicit text genre instruction on the performance of second and third grade students. Over a two-year period, students received instruction in science that included authentic literacy experiences or authentic literacy experiences plus explicit instruction in how to read and write informational and procedural texts in science. Teachers under both conditions received ongoing professional development and support from university personnel in implementing the research conditions. While the effects of authentic literacy activities on performance were strongly correlated with student performance, results demonstrated no significant impact of the explicit teaching of text genre on a majority of the performance outcomes. These results conflict with the notion that academic discourses and genres are best learned through explicit instruction.

In their discussion, the authors acknowledge the complexity of their study, offering varying explanations for their findings. One explanation is the possibility that students as young as third grade may not be developmentally ready for explicit text genre instruction and that possibly this type of instruction would be more effective at the secondary level where students have more exposure to reading these types of texts. They also consider the possibility that explicit teaching of genre function might be more effective if combined directly with explicit instruction in reading and writing strategies related to the genre. Purcell-Gates et al. (2007) summarize “We need to know much more about which aspects of which types of language knowledge and growth are amenable to explicit instruction (p. 41).

While this research raises questions about the call from many science and literacy experts to teach students explicitly about features of science texts, it is only one study and it opens the possibilities for much more research in this arena. The issue of how language is a part of academic learning is complex and the right combination of authentic literacy activities and explicit instruction is still unknown. In addition, there is relatively little work done in secondary classrooms in regards to integrating language and science. More empirical work in this area needs to be conducted.

Disciplinary Literacy

Recent scholars in the field of literacy have started to look at the concept of disciplinary literacy, a new vision of the traditional concept of content literacy (Moje, 2008; Shanahan & Shanahan, 2008). The idea of disciplinary literacy embraces the notion that disciplines have particular ways of using language and literacy to communicate information in that discipline. For example, in science the language and literacy tasks are specialized to meet the needs of writing and communicating about science. Likewise, in history, the language and literacy tasks serve to communicate historical information. Disciplinary literacy focuses on how writers in particular disciplines use language and literacy to build knowledge of that discipline (Moje, 2008).

Shanahan and Shanahan (2008) conducted a two year study examining how disciplinary experts approached reading in their disciplines and then how that knowledge could be transferred to teaching high school students to read in particular disciplines. In the first year of the study, the researchers formed teams around three disciplinary areas: chemistry, history, and mathematics. Each team consisted of two disciplinary experts who were researchers in the field, two teacher educators, two high school teachers, and two literacy experts. Teams were posed with two tasks in order to identify the specialized reading processes for each discipline. The team initially met and analyzed various texts to discover how they approached the reading of the text and then to explain the reasons the team felt the texts might be challenging to students. The next task involved asking each team member to read and think aloud about their own reading approach to reading in their disciplines.

Findings from the first year confirmed that members of each team viewed reading similarly in relation to their discipline. Teams were then asked to propose a list of strategies that could be useful to help students read in their discipline. The next phase of the study involved the high school teachers from the teams taking those strategies into their classrooms. Those teachers then reported back to the disciplinary team with student samples and feedback for further analysis. This study concluded that traditional efforts that infuse general comprehensions strategies across the content areas are in need of revision. Shanahan & Shanahan (2008) argue that this study reinforces that experts in particular disciplines use language and literacy in ways that are specialized to that discipline and therefore the strategies teachers use to help their students learn to read in a particular discipline should reflect the way that experts in the fields read.

Literacy experts are rethinking traditional means of addressing reading in the content areas (Draper, 2008; Moje, 2008; Olson & Truxaw, 2009; Shanahan & Shanahan, 2008). The idea of disciplinary literacy moves the focus from incorporating generalized reading strategies into subject areas to using discipline specific literacy strategies that come from within the discipline. This shift in thinking contributes to the complex question of how literacy and content experts can work together to improve adolescents' reading in secondary settings.

Much work is needed to confirm the best ways to address issues of disciplinary literacy in classrooms. Empirical evidence supporting the teaching of disciplinary literacy in the classroom is lacking.

The Specialized Language of Science

Numerous calls from researchers and organizations have been made for secondary teachers to address the specific ways that literacy is used in content areas (Biancarosa & Snow, 2004; IRA & NMSA, 2001; Moore, Bean, Birdyshaw, & Rycik, 1999, Heller & Greenleaf, 2007). The National Council of Teachers of English (NCTE) (2007) supports the need for secondary teachers to provide explicit instruction in both the content and the literacy demands of each academic area. Heller & Greenleaf (2007) further claim that it is essential that secondary teachers understand the reading and writing skills that are unique to their discipline in order to show students how to use and apply the language of a particular content area. In order to do this, teachers must themselves develop an understanding of how language is characteristically used to construct content in their subject areas. Scholars (e.g., Fang & Schleppegrell, 2008) have suggested that as students move into the secondary school, they encounter texts that deal with more specialized topics and use language that is more complex than those they typically read in the elementary school. Understanding discipline-specific ways of using language is a key to learning the content of the discipline.

Current recommendations for content reading instruction focus on basic, generalizable reading skills and strategies (e.g., phonics, fluency, cognitive/metacognitive strategies) without attending to the specific language demands of science reading (Fang, 2008; Kamil & Bernhardt, 2004). While research has shown some success with integrating reading strategy instruction into science curriculums at the elementary and middle school level, performance in secondary testing and post-secondary testing on science literacy tasks demonstrates that students are graduating from high school without being scientifically literate. One explanation for this could be because the demands of reading science information at the secondary level are more complex and challenging than at the elementary level and therefore teachers must go beyond these basic, generalizable reading skills and strategies to attend to the specialized discourse of science to continue developing students' science literacy.

Teachers often assume, however, that by the time students reach middle and high school they are able to read. Secondary teachers focus their instruction on subject matter knowledge, often assigning reading as a task to be completed, not taught. As content specialists, teachers at this level are comfortable and familiar with the nuances of science discourse and often do not recognize that the patterns of the language in science are seemingly foreign to many secondary students. Teacher's inattention to the matter of how to read science discourse often makes students feel alienated and disconnected from the course material (Halliday & Martin, 1993).

The science language of secondary learning is vastly different from the language of elementary school learning where concepts and ideas are more closely tied to students' everyday lives. In secondary settings, science concepts and ideas are more distant from the everyday experiences of students (Fang, 2006; Veel, 1998). The language that constructs scientific knowledge, principles, and world views is highly specialized in more advanced science reading (Halliday & Martin, 1993). In science, texts are predominately expository and analytical expressing logical relationships among abstract processes and ideas through strategies such as taxonomies and classification (Lemke, 1990). Therefore, students need guided and extended practice in reading the content area of science in the secondary school.

As students move into more advanced literacy experiences in secondary science classrooms, they need to obtain strategies for engaging with the linguistic challenges of more advanced scientific texts (Christie, 1998; Schleppegrell, 2004). Language constructs knowledge in particular ways in science to make it functional for the field of science. For example, scientists discuss science concepts in an abstract manner that emphasizes the process and outcomes, not the human agencies involved. This way of using language in science makes the information appear more objective and authoritative (Halliday & Martin, 1993; Schleppegrell, 2004). Scientists use language to convince readers of interpretations of results from scientific investigations. Being able to recognize the ways that scientists use language to present their ideas can help students grasp more advanced science concepts (Wellington & Osborne, 2001).

While it is valuable to expose students to various authentic types of scientific texts, it is equally important to provide explicit instruction in how to comprehend these types of texts. Mere exposure is insufficient to guarantee that students gain the necessary skills to critically read and evaluate scientific information. Therefore, it is imperative that students understand the features of scientific discourse

The Specialized Features of Science Language

Science is a discipline aimed at describing, explaining, analyzing, classifying, comparing, generalizing, hypothesizing, theorizing, and arguing about phenomena in the natural world. In order to do this, scientists have unique ways of using language. The following section will explain and discuss two key constructs of science language: genre and register.

Genre

To begin, science discourse has a complex organizational structure. As opposed to the typical predictable structure of narrative writing, the structures used in science discourse are much more varied and complex, depending on the purpose of the text. These structures have been identified by linguists as text genres, the way that language is organized to serve a particular social purpose, e.g., to inform, to instruct, to explain, to discuss. According to Veel (1997), there are seven major genres in science: procedure, recount, explanation, description, report, exposition, and discussion. Each of these genres has its own structural and grammatical features. Understanding what these features are is critical to the development of science literacy. Schleppegrell (2004) identifies the following text genres as most common in school science reading: Procedure, procedural recount, science report, and science explanation (p. 115). Each of these genres is explained with an example below:

Procedure

Schleppegrell (2004) defines the purpose of the procedural genre to provide instructions for how to conduct experimental activities. The structure of this genre is unique and typically contains a series of sequential steps that tell the reader how to do something, like following a recipe. Other features of this genre can include a list of materials or a goal statement for the outcome of the experiment. This genre employs a declarative mood with verbs written in the present tense (e.g. you take off the top of the can and place it in the basket). In addition, command words like pour, cover, and remove direct the reader in what to do. Also, transition words are commonly used in this genre like next, then, and after. This is typically one of the first genres students experience in science. The following example is extracted from directions for how to build a spectroscope found on the Exploratorium web site, an online educational site sponsored by the Exploratorium, a museum of science, art, and human perception founded in 1969 in San Francisco, CA.

> Next, using your scissors cut one of the index cards in half. You will use each half of the index card to make a slit in the end of the shoe box. Place the two halves of the index card over one of the holes, creating a vertical slit (about 3/16" wide). Tape these pieces in place using masking or scotch tape.
>
> Next, cut out one eyepiece of the rainbow glasses (or a piece of diffraction grating) and place it over the opening on the shoe box. Lightly tape the diffraction grating in place. (excerpt from http://www.exploratorium.edu/explore/handson.html)

Procedural recount

The purpose of this genre is to record information about what has happened in an experiment (Schleppegrell, 2004). The aim is to retell the events of an investigation. The structure of this genre usually contains steps that explain the methods and processes the writer used to conduct an experiment. Included also are statements of the purpose and the results. Language features of the procedural recount genre include use of action verbs in the past tense (e.g. we saw, we noticed, we observed). The declarative mood is used like in the procedure genre. In addition, references to specific nouns to name people and things are evident in procedural recount. Another feature of this genre is the use of material processes to construct events (e.g. ice floats on top of the water). Also, cause and effect statements are typically used to show relationship between events in an experiment Following is an example of a procedural recount about the water cycle.

> (Purpose) Today we did an experiment to demonstrate the energy of the sun and to construct a model of the water cycle. (Steps) First we filled a third of a bucket with water that contained a cup of soil, a handful of salt and several leaves. We then put a mound of plasticine in the bottom of the bucket and stuck a plastic cup onto the mound with Blutack. Next we placed Clingwrap over the bucket and taped it down to make it secure. We put three of four marbles directly over the cup so that the plastic sagged and left it in the sun for a few hours. (Results)When we came back we saw that the water evaporated to the clingwrap where it cooled and condensed. Then the droplets joined together and then it fell into the cup. This is called precipitation. The water was clean because the sun only pulls up water not salt. This means that we had made a model of the water cycle. (from http://www.decs.sa.gov.au/accountability/files/links/ProceduralRecount_051206 pdf)

Science report

The purpose of this genre is to relate a set of facts about a topic. Halliday and Martin (1993) identify this genre as the most used in schools. Information in this genre is typically organized by classifying, dividing phenomena into parts and wholes, or describing or listing its properties. The structure of this genre usually begins with a general statement that organizes and introduces the topic (i.e. animals are divided into groups based on what they eat) and then the rest of the report is organized by parts that connect back to the main topic (i.e. carnivore, omnivores, herbivores). Participants in reports are usually generic (i.e. animals, plants, cells). The language characteristics of this genre include use of technical terms, like carnivore, omnivore, and herbivore. The use of these technical terms creates new meanings that are unique to science and serve to represent specific scientific phenomena. Relational process clauses describe the technical terms and make connections between ideas (e.g. the giraffe is an herbivore). Another distinct linguistic feature of the science report includes the use of timeless verbs in simple present tense (divides, plays, distinguishes) and a large percentage of being and having clauses (e.g. have, are, were). Following is an example of science report:

> The animal kingdom is made up of many different animals. In a way they all need to work together in order to survive. Each animal needs another animal or plant for survival. It starts from the smallest of animals and continues on, all the way up to the largest.
>
> This togetherness is called the food chain. The smallest animals in the chain will be the ones that do not eat other animals, but eat plants and fruits, vegetables, and seeds that come from plants instead. These are called herbivores. The rest of the animals in the chain are called either carnivores or omnivores. Carnivores eat only meat, which, of course, is other animal. Omnivores eat from both food groups, so that means they eat what both carnivores and herbivores eat. Humans are omnivores (from http://www.associatedcontent.com/article/375038/homeschool_science_lesson_plans_food.html)

Science explanation

The purpose of this genre is to describe how and why scientific phenomena occur. For example, how an ecosystem is structured. In this genre, a more authoritative voice is operated to provide a convincing explanation. The organizational pattern is logical in order to develop and explain a theory for why a certain scientific phenomenon is what it is. The theory is constructed through cause-effect relationships and logical sequencing of events. Linguistic features of this genre include relational processes and technical language. In this genre there are a higher percentage of action verbs also (accumulates, forces, forms). Participants are usually generic in this genre. Following is an example:

> In a lake ecosystem, the sun hits the water and helps the algae grow. Algae produce oxygen for animals like fish, and provide food for microscopic animals. Small fish eat the microscopic animals, absorb oxygen with their gills and expel carbon dioxide, which plants then use to grow. If the algae disappeared, everything else would be impacted. Microscopic animals wouldn't have enough food, fish wouldn't have enough oxygen and plants would lose some of the carbon dioxide they need to grow. (from http://www.nhptv.org/natureworks/ nwepecosystems.htm).

Science exposition

Halliday & Martin (1993) also note that while the above mentioned genres are the most common in school, the genre of exposition is also important in science text. Exposition is used to present arguments in favor of a position in science. The purpose of exposition is to persuade the reader to think or act in a particular way about a topic. Identifying structural features of this genre include a thesis statement and arguments that reinforce the thesis statement. Grammatical features include adjectives and adverbs that convey value and judgment, technical terms, logical conjunctives, and a variety of verbs. Following is an example of exposition in science text:

> The red wolf was once the top predator in its habitat. Writings dating back several centuries refer to wolves similar to the red wolf in what is now the southeastern United States. Many researchers believe that red wolves have shared the North American continent with humans for thousands of years. Native Americans revered the wolf. The red wolf was known as "Wa'ya" to the Cherokee; the "Ani'-Wa'ya" or Wolf People were the principal clan.
>
> Summit predators play a positive role in maintaining healthy ecosystems. They help to ensure the natural hierarchy of animal species by keeping the numbers of prey populations in balance. Rather than eliminating large predators, humans must make a concerted effort to preserve them as necessary elements in regulating the food chain.

> One of the most important reasons for protecting red wolves is the awareness that every species has intrinsic worth. The red wolf is a unique animal that contributes to the overall biodiversity of the ecosystem. But it has an aesthetic value as well as a practical one. Red wolves are beautiful. If they vanish from existence, we humans as a species are diminished. For all these reasons, we must protect and preserve this critically endangered animal. (http://www.fws.gov/redwolf/ft/005Rw_future_and_protection07.pdf)

Register

The major scientific genres serve to organize scientific information in a way that reflects how scientists think about phenomena. But in addition to the genres, it is also necessary to recognize the way that scientists use language within those genres to express scientific ideas. The term register is used to explain how a writer uses language within a specific discipline. Schleppegrell (2004) defines register as “the configuration of lexical and grammatical resources which realizes a particular set of meanings” (p. 45). Scientists have unique ways of writing that make science discourse unique and challenging. Science language is simultaneously technical, abstract, and dense (Fang, 2005). Each of these register features of science discourse is elaborated below:

Technicality

Science is technical because it uses a set of vocabulary words that have been coined specifically for science (e.g., lithosphere, plate tectonics). These words make science unique and specialized. Technical words such as photosynthesis that describe key concepts or nocturnal that describe an animal’s behavior are found only in science related reading and must be understood in order to comprehend important science concepts. These types of technical terms can be separated into naming words (e.g., chromosome, cell, mitochondria), classifying words, (e.g., carnivore, vertebrate, vascular), process words (e.g. photosynthesis, reflection, reproduction), and describing words (e.g., nocturnal, alkaline, acidic). Without these words science would be incomplete and imprecise (Fang, 2006).

In textbook reading, these words are often highlighted or featured in distinct ways through illustrations or diagrams. For example, the word photosynthesis might be accompanied by a diagram showing how a plant processes energy from the sun. In school, these words often become the focus of vocabulary lessons in science. However, discreet learning and memorization of these words does not always aid students in comprehension. Often in science texts, a heavy concentration of these technical words occurs. In the following excerpt from an online biology textbook *Rediscovering Biology*, 53% of the total words are accounted for by technical vocabulary.

> (1). Mutations in a target protein that affect binding of an antibiotic to that protein may confer resistance (from http://www.learner.org/channel/courses/biology/textbook/index.html)

In addition to these specialized words, though, science also uses common everyday words in technical ways. For example, in geology, the word “fault” means the displacement of rock layers in the Earth’s surface, not that someone made a mistake. Other examples of words that take on specialized meaning in science include medium, frequency, matter, charge, and volume. These words are familiar to students in their everyday language, yet when presented in science, these words construct new meanings. Even though these words appear simple and decodable, they often interfere with students’ comprehension and are overlooked by teachers as being problematic. The following sentences demonstrate how multiple meanings of common words are used in science writing.

> A liter is a measurement of liquid volume. (the amount of space an object occupies vs. loudness of a sound).

> Fishes that swim in schools are often safer than fishes that swim alone because it is harder for predators to see and select an individual fish. (groups vs. educational institutions).

These technical words can hinder students' comprehension if not addressed in instruction by teachers. In addition to the specialized vocabulary words of science, the common ordinary words that are used in special ways in science require attention in science reading instruction (Fang, 2006).

Abstraction

Another feature of science is that it uses language that is more abstract than our everyday language. In everyday language the subject of sentences is often a pronoun (e.g. she, they, we). However, in science the subject of a sentence typically refers to a class of things (e.g., vertebrates, invertebrates) or abstract identities (e.g., this process, consumption of material goods).

Nouns that appear in science texts are often not persons, places, or things; they represent processes or qualities in what linguists refer to as nominalizations. Nominalizations such as distillation, significance, and revelation allow scientists to abstract away from immediate, lived experiences in order to create technical taxonomies, to synthesize detailed information, to build theories, and to develop a cohesive chain of reasoning (Veel, 1997). As such, nominalizations have been shown to pose comprehension challenges to adolescent readers.

In academic texts, this process of changing verbs into abstract noun phrases is common. Scientists use nominalization to present arguments or theories in a manner that appears objective. This strategy of using nominalized phrases allows scientists to construct hierarchies of technical terms, to use classifying and describing to explain things, and to synthesize previous information about a topic so that it can be elaborated upon in further discussion (Halliday, 1998; Fang, 2006). For example, the following excerpt from an online NASA article takes the verb consume and presents it as consumption. The process of using the materials listed in the first two sentences is condensed into an abstract noun phrase “the consumption of material goods.” The phenomena of how material goods are used is synthesized with the words “the standard of consumption.” Using the word consumption turns the verb consume into a thing and allows the writer to further develop arguments and explanations about the use of food.

> Closely tied to the question of having enough food for survival is the idea of having enough fuel, clothing, and building materials for survival. The availability of everything from firewood to winter coats begins with plants. Consumption of material goods is an important factor in economic stability and security, as well as in maintaining or improving lifestyle levels. The more a population consumes, the more effort it takes to maintain that standard of consumption. Imhoff found that there were two big factors that lead to high consumption levels. The first is high per-capita consumption rates, as seen in much of the developed world; the second is large populations. Even a low per-capita consumption rate can result in a huge overall level of total consumption if multiplied over a large number of people. (excerpt from http://nasadaacs.eos.nasa.gov/articles/2007/2007_plants.html).

When a chunk of text is condensed into a noun clause like “consumption of material goods” some semantic information is buried. The reader must make connections between previously read information in order to diagnose that “consumption of material goods” is referring to using items such as winter coats, building materials, and firewood. The process of nominalization in science language can obscure meaning by creating words that are more ambiguous and abstract to the reader.

Nominalization is a commonly used grammatical tool in environmental texts because it suppresses agency, allowing the social agents responsible for the environmental problems to not be identified. In the above excerpt nominalizations such as consumption of material goods conceals the party (e.g. people, businesses) responsible for doing the consuming and impacting economic stability. This omission of social actors allows the text to focus on what is happening- the rate of consumption- versus who is doing it- the population. Being aware of how scientists use language to condense words into abstract noun groups can help students in understanding scientific texts.

Density

Not only is science discourse technical and abstract, it is also dense. Scientists can pack a large amount of information into one sentence. The density of science discourse is achieved primarily through the use of long, complex noun phrases, such as the underlined portion of the following sentence extracted from a biology text: "The complement of proteins found in this single cell in a particular environment is the proteome" These lengthy noun phrases are common in science writing and increase the print processing demands for readers.

This writing is different from typical everyday language where ideas are separated into multiple sentences. In science writing, ideas are often expressed in single sentences. Consider the following sentence from a biology textbook explaining characteristics of cancer cells

> Although cancer comprises at least 100 different diseases, all cancer cells share one important characteristic: they are abnormal cells in which the processes regulating normal cell division are disrupted (from)

In everyday language, this information might be expressed as follows: “Cancer is made up of 100 different diseases. But, all cancer cells have one thing in common. The cancer cells are different from normal cells. Cancer cells do not have the same cell division process as normal cells.” Notice the shorter, simpler nouns and multiple sentences used in everyday language compared to the longer, more complex nouns consisting of just one sentence used in the scientific description.

The density of a text can be measured by an index called lexical density. Lexical density is based on the number of content words per non-embedded clause. The greater the number of content words, the greater the lexical density. Halliday & Martin (1993) explain lexical density as, “a measure of the density of information in any passage of text according to how tightly the lexical items (content words) have been packed into the grammatical structure” (p. 76).

Embedded clauses are used to create the complex, information loaded sentences of science texts. The embedded clause is a clause that does not function independently. The following sentence contains two clauses. Mutations in a target protein that affect binding of an antibiotic to that protein may confer resistance. The main clause is, “Mutations in a target protein . . . may confer resistance”. In this sentence the clause - that affect binding of an antibiotic to that protein - is embedded to delineate the type of mutation being discussed. This embedded clause allows the writer to add more information to the sentence. Notice the underlined words in the sentence. There are 9 content words in one sentence. If the writing was simplified- two sentences could be used. Mutations in a target protein affect binding of an antibiotic. Those mutations to that protein may confer resistance. In this case the average drops to 4-6 content bearing words per sentence.

As lexical density increases, the level of difficulty of a text increases. In conversational language, the lexical density is lower, usually 2-4 words per clause. But, in more formal, written language the lexical density it typically much higher, averaging 4-6 lexical words per clause. In looking specifically at science writing, the lexical density is even higher than the typical written language, averaging 10-13 lexical words per clause (Halliday & Martin, 1993, p.76).

Consider the following passage from a biology textbook. The lexical density of this passage is 10.6. There are 3 clauses and 32 content words.

> The proteins made by tumor suppressor genes normally inhibit cell growth, preventing tumor formation. Mutations in these genes result in cells that no longer show normal inhibition of cell growth and division. The products of tumor suppressor genes may act at the cell membrane, in the cytoplasm, or in the nucleus.

The high lexical density of science writing makes it challenging to read. Scientists use lengthy, complex noun groups to pack a lot of information into each clause. The use of embedded clauses in science writing makes it more formal and specialized. If teachers gain an understanding of density in science writing they can help students to break it down into understandable parts.

To summarize, the technical, dense and abstract nature of science discourse heightens the need to focus on the unique ways language is used to communicate scientific knowledge and values in science reading instruction. Understanding the structure and purpose of text genres as well as, the register features of science discourse can lead teachers to help students to improve their comprehension of science reading materials. This could lead to the overall increase of students' science literacy.

Science Teachers' Beliefs and Practice of Content Literacy

Beliefs are deeply linked to teachers' practices (Fang, 1996; Hall, 2005; Johnson, 2006; Munby, 1982; Pajares, 1992; Waters-Adams, 2007). Research indicates that in order to transform instructional routines, teachers' beliefs about teaching must be considered (Fang, 1996; Luft & Roehrig, 2007; Munby, 1982; Richardson, Anders, Tidwell, & Lloyd. 1991; Richardson, 1996). In this review of the research, I will first discuss the role of beliefs in shaping science teachers' practice. Next, I will discuss science teachers' beliefs about science and literacy. I will then consider barriers to integrating literacy into science teaching at the secondary level. I will close this discussion with a consideration of recommended practices for changing teacher beliefs about the integration of reading and science.

Role of Beliefs

Research on teacher beliefs is substantial (Fang, 1996; Luft & Roehrig, 2007; Munby, 1982; Nespor, 1987; Pajares, 1992; Richardson, 1996). The onset of constructivist teaching paradigms has inspired researchers to explore how teachers' beliefs are tied to their practice. Extensive research has examined the impact of beliefs on teacher thinking and decision making (Linek, Sampson, Raine, Klakamp, & Smith, 2006; Munby, 1982), the relationship between belief systems and knowledge (Pajares, 1992) and the alignment of beliefs with teachers' instructional choices (Powers, Zippay, & Butler, 2006; Richardson et al, 1991; Ruddell, 1997; Waters-Adams, 2006). It is generally agreed that an acknowledgement of teachers' beliefs is necessary in order to affect changes in educational practices (Pajares, 1992).

The construct of a belief however is complex. Teachers' belief systems about education are wide-ranging including beliefs about how to affect student performance, student behavior and learning, causes for school climate issues, confidence to execute specific tasks, the nature of knowledge, and the nature of specific disciplines (Pajares, 1992). Though there is strong agreement that beliefs impact behaviors (Bandura, 1986, Ernest, 1989, Fang, 1996; Luft & Roehrig, 2007) zeroing in on how teachers' beliefs impact teaching practice is complicated in the least.

Studies indicate that many factors influence teachers' beliefs. Teachers often rely on teaching methodologies that they have experienced as students to inform their beliefs about teaching and learning (Linek et al., 2006; Willis & Harris, 1997, Tsai, 2002). Other factors such as experiences in teacher preparation programs, school environment, teaching experiences, and professional learning events strongly influence what teachers believe about teaching (Fang, 1996; Linek et al., 2006; Luft & Roehrig, 2007). The compilation of individual teacher experiences creates unique and particular belief systems, challenging those who plan for teacher learning.

Pajares (1992) argues that investigations into teacher beliefs need to be context-specific, taking into consideration individual teacher's experiences working within their content. In science education, recent research focuses on how science teachers' beliefs impact their acceptance and implementation of reform- based inquiry methods into their teaching (Levitt, 2001; Tsai, 2002). A recent study by Waters-Adams (2006) testifies to the importance of beliefs to teachers' actual teaching practices. Through action-research, Waters-Adams studied four teachers' understanding of the nature of science and their science instruction. He observed that the teachers' espoused positions about the nature of science were in conflict with their daily instruction. Even though each teacher claimed to view knowledge in science as hypothetico-deductive, all teachers delivered science lessons as a body of knowledge to be learned, relying more on their own personal experiences with learning science rather than what they had learned about teaching science.   Waters-Adams further examined teachers' general beliefs about teaching, learning, and curriculum and discovered again that teachers' practices did not reflect their espoused beliefs about education. The teachers eventually aligned their understanding of the nature of science with their actual teaching practice through extensive reflection on the relationship between their belief systems about education and science and their practice. Water-Adams conclude that science teachers need to engage in articulation about their beliefs about teaching and the nature of science in order to fully understand and implement their instructional choices.

This information about how beliefs about content influence instructional choices is important when planning for integrating reading into science teaching. If teachers' actual teaching practices are influenced by their experiences then it is important for researchers to understand how science teachers believe that reading is a part of science learning. Possibly, the science teacher must first believe that reading is a necessary part of knowing and doing science in order to be willing to try instructional strategies that support integrating reading and science.

Beliefs about Science and Literacy

It is widely acknowledged that teachers' embedded beliefs about teaching and literacy influence their instructional decisions (Ernest, 1989; Hall, 2005; Munby, 1982). In an extensive review of the literature on content reading, Hall (2005) summarizes that it may not be just a lack of knowledge in what to do to infuse reading into content instruction, but also an issue of inherent teacher belief systems that impacts content teachers’ classroom practice. It is important to understand the beliefs teachers hold about the role of reading in learning and teaching their discipline.

There is considerable evidence that teachers’ instructional practices are linked to their philosophies about their content. Dillon, O-Brien, and Moje (1994) followed three exemplary science teachers for one year looking at how they incorporated literacy activities into their science teaching. Data from field notes, audio-transcripts, and interviews were cross analyzed. Researchers noted that teachers used literacy strategies to enhance their own philosophies of science. For example, one teacher used cooperative learning groups, study guides, daily writing, and discussions to encourage science learning. His study guides reinforced his belief that students should use reading in science to learn from science materials. This teacher further modeled how to break the textbook reading into small chunks and ask questions during reading to demonstrate his belief about the role of reading in science learning. Another teacher in the study controlled more of the learning in his classroom. He began more of his lessons with lectures and depended less on the textbook reading and more on lecture notes and group work in laboratory activities. Dillon, O-Brien, and Moje (1994) conclude that the teachers’ used literacy as an instructional tool to support their personal philosophies about science and science learning.

In another study, Moje (1996) discovered that a chemistry teacher valued literacy in her classroom as a tool to organize and remember information. The researcher spent two years as a participant-observer in a veteran chemistry teacher’s classroom looking at the social and cultural influences on the use of literacy strategies. Data sources included field notes from observations, interviews with seven student informants, informal conversations with teacher and students, audio-and video- transcripts from daily lessons, and artifacts such as handouts and student work samples. Her analysis noted that literacy in this classroom was used as a tool for organizing thinking and learning about chemistry and that the teacher's philosophy of science influenced how she perceived literacy as being useful in her content area. For example, strategies like SQ3R and concept mapping were frequently used. This was evidence of the teacher's value in having students use reading strategies to organize their learning. Moje further learned that many of the ideas the teacher implemented in her classroom were drawn from the teacher's own life experiences as a student and as a teacher. From her study, Moje (1996) recommends that literacy educators spend more time understanding the way a content teacher's beliefs about their content influence how they uses literacy in their content area, not just their beliefs about literacy.

In another study, Ritchie & Cook (2001) found similar` results from their 5-week observation of a grade-8 science class. The researchers analyzed data for evidence of dialogic discourse and transformative understanding, arguing that in order for students to be part of the science discourse community they need to engage in the types of conversation in the classrooms that promote scientific literacy. From their observations, researchers noted, however, that most of the conversation was univocal- the teacher's dominant mode of teaching was lecture. These actions were connected to the philosophy of the teacher who believed that he was the authority in the classroom and at the middle school level; students just need a basic level of understanding, which was seen by the expectation that students would be able to recall textbook definitions of terms. The researchers further noted that students were not able to sustain dialogic conversations during lab work. Most comments were procedural or relied on textbook definitions or information to try and understand a phenomenon. The researchers conclude that the teacher highly influences how students participate in literacy activities in the classroom and that the teacher needs to serve as a model for how to engage in scientific discourse.

These studies taken together reinforce the notion that personal philosophies and beliefs about teaching, learning, and content are highly influential in the instructional choices that teachers make. In each case, teachers used literacy tasks to support their beliefs about science and science learning.   This research confirms the importance of understanding how science teachers' view the role of reading in learning science.

Barriers to Integrating Reading and Science

There is evidence through research that science teachers and other content teachers generally believe that reading is an important component of their discipline (Digisi & Willett, 1995; Lipton, 1978; Stieglitz, 1983; Vigil & Dick, 1987). Yet, it has been well-documented that infusing reading into secondary content areas has met with limited success and some resistance (Alvermann & Moore, 1991; O'Brien, Stewart, Moje, 1995; Vigil & Dick, 1987). Research has considered various explanations for this dissonance between what teachers report to believe about reading in their content and their actual use of reading as part of their teaching practice.

Yore (1991) for instance concluded that many science teachers lack substantive knowledge about how to teach students the metacognitive and cognitive skills required to read science effectively. Through surveys and interviews, Yore established that science teachers value reading and the reading process and further, accept that it is their responsibility to attend to teaching students how to read science content.

However, the interviews did detect that teachers believed their primary goal was to relate science content to students. Yore recommends that science journals need to report more science reading applications to inform the science teaching community about how to infuse reading into their curriculums. This study is important because if teachers do believe that ultimately reading is an integral part of their discipline, it may be easier to convince science teachers to adapt their instruction to include explicit focus on how to read science content.

A later study on how high school biology teachers use their textbooks further supports the notion that science teachers believe that reading is an important means of learning science but are uncertain of how to incorporate reading into their daily instruction. Digisi & Willett (1995) found that teachers used textbook reading for a variety of reasons including to reinforce previously taught concepts, to supplement and extend ideas, and to introduce new topics. However, reading was rarely used as a means for independent learning and teachers reported minimal use of using the textbook as a tool to assess how well students could read science materials. Digisi & Willett note that high school biology teachers reported use of their textbook does not align with current research about best practices in reading in content areas. The researchers recommend that reading and science educators collaborate to develop models for how to infuse reading strategies into science learning so that students learn how to construct meaning form their science texts.

These studies are promising for teacher educators hoping to impact current science teachers' use of reading in their curriculum. In both studies, teachers appear to have an inherent belief that reading is valuable in teaching and learning science. The roadblock to implementing reading effectively though is in teachers' knowledge and confidence in how to make it a part of their daily instruction. If this is the case, then professional development in science should include more explicit instruction in how reading can be incorporated into the instructional routines of science teachers and provide strong support for science teachers who are willing to try.

In addition to the research directly addressing what influences secondary science teachers use of reading, it is important to consider some general findings from research across content areas about barriers to teachers' incorporation of reading into content curriculums. Research identifies two barriers that impact teachers' attitude towards implementing reading into content instruction: time and school structure.

Teachers often report that they do not have time to learn about reading (Sturtevant & Linek, 2003; Simonson, 1995). They view reading at the secondary level as an add-on to what they are already doing and blame teachers at the elementary level for students' lack of reading skills (Campbell & Kimeck, 2004). Another issue of time is that there is often not enough room in the daily schedule for teachers to communicate and collaborate with peers regarding literacy issues (Daisey & Shroyer, 1993). Also, because the secondary setting is traditionally still separated into multiple periods throughout the day, teachers state that there is not enough time within the instructional period to incorporate strategy instruction (O'Brien, Stewart, & Moje, 1995; Sturtevant, 1996). Teachers report feeling pressure to keep on schedule with curriculum mandates makes it challenging to devote instructional time to how to read content (Allington, 2002; Bintz, 1997; Sturtevant, 1996).

Issues around school structure further antagonize the successful integration of reading into secondary curriculums. Research has overwhelmingly confirmed that school leadership plays a major role in whether or not content teachers integrate reading into their instruction (Richardson et al., 1991). In addition, the philosophy of individual departments and how congruent fellow teachers' beliefs are about reading integration impact whether a teacher feels comfortable trying new strategies (Dieker & Little 2005; Sturtevant, 2001). In addition, the curriculum throughout secondary classrooms is increasingly mandated by districts and driven by assessments, resulting in high stakes accountability (Hagar & Gable, 1993; Konopack & Readance, 1994). Teachers feel tremendous pressure to cover content and prepare students for standardized tests leaving them feel disempowered to make changes to their instruction (Dieker & Little, 2005; Jackson and Cunningham, 1994; Sturtevant, 1996). Other issues related to school structure include class size and student behavior. Although many schools now employ reading specialists or coaches to help content teachers meet the needs of their students, often this relationship is strained and ineffective due to lack of training and time for planning (Lipton & Liss, 1978). Findings from these studies suggest that content teachers are willing to infuse reading into their content areas, but a lack of knowledge in how to do it or external barriers like time and school structure inhibit the successful implementation of reading into daily instructional practices.

This body of research about science teachers' beliefs and practices in content literacy is important in the planning of this study. First of all, if the goal of my research is to transform science teachers' use of discourse strategies in their teaching, the role of teacher beliefs about science discourse must be considered. I must employ a means of discovering and addressing how the teachers in this study believe that reading plays a role in the learning and doing of science. I must also diagnose teachers' current use of reading in their teaching and build on what they already know and believe about reading as a necessary part of their daily instruction. In addition, I must observe and consider how the school structure and leadership either support or inhibit these teachers' risk taking in trying new strategies in their classrooms.

A common vehicle for changing teachers' beliefs and practice is through professional development (Brownell, Leko, Kamman, & Streeper-King, 2008; Guskey, 2002). In the following section I will address how effective professional development can impact changes in science teachers' acceptance of and practice of using reading in their content area. I will begin by considering what conditions of professional development cultivate changes in teacher beliefs. I will then examine the nature of teacher knowledge and its development. Next I will consider factors that encourage teachers' transformation of their instructional practice.

Professional Development and Science Teachers' Learning

One of the main ways to impact the practice of teachers in the field is through professional development efforts. Recent research on effective professional development shows that certain conditions can positively impact the beliefs and practice of science teachers.

Cultivating Change in Teachers' Beliefs

Teacher belief systems are powerful constructs, yet recent studies reveal that particular conditions of professional development both support and promote change in beliefs. Professional development that encourages peer collaboration, critical conversation, and reflection allows teachers to examine how their beliefs coincide with what is being studied (Brownell et al., 2008; Feiman-Nemser, 2001; Richardson, 2003). In addition, longevity is a key component. Sustained professional development provides teachers with ample time and evidence to support changes in beliefs (Dupuis, Askov, & Lee, 1979; Glasson & Lalik, 1993). Finally, active participation in the professional development process provides teachers with a safe place to practice and experiment with new ideas, building their confidence to try it out in their own classrooms (Darling-Hammond & McLaughlin, 1995; Desimone, Birman, & Yoon, 2001; Garet et al., 2001).

In a study of 6 science teachers, Glasson & Lalik (1993) determined that teachers' beliefs of the role of language in learning science changed as they engaged in sustained reflective thinking and conversation about the integration of the learning cycle model into their science teaching. The professional development model included opportunities for teachers to talk about practice, try new strategies in the classroom, and reflect on the effectiveness of those techniques. One teacher cited noticing changes in student motivation due to her changed methods and beliefs about the place of language and action in science. In this case, the conditions of longevity, reflection, and active participation made an impact on the science teachers' beliefs and ultimately, their practice.

An overriding question though in the beliefs and professional development literature is what comes first, change in beliefs or change in practice? Guskey (2002) claims that the most powerful element in changing teachers' beliefs is change in student outcomes. From his research, Guskey concludes that evidence of student improvement must precede change in teacher beliefs. Professional development can serve as a catalyst to learn about new ideas, but it is not until teachers see a positive impact on student learning that they are willing to change their beliefs. Fang et al. (2007) observed this cycle of change in two middle school science teachers who participated in a university-based partnership in reading integration. These teachers spent 15 weeks working with university personnel to implement weekly reading lessons into their science curriculum. It was not until teachers' saw the impact of the weekly lessons on the improvement of students' test scores in reading and science literacy that they fully bought into the concepts presented to them through the collaboration and embraced the new teaching strategies into their repertoire of teaching.

Though teacher beliefs are powerful and deeply rooted, evidence shows that beliefs can be altered through professional development if the right conditions are met. In planning for this professional development in science literacy, I will need to provide time for teachers to practice the ideas that I share. In addition, Opportunities during the professional development for teacher to talk about their practice and reflect on the usefulness of the strategies will be vital to getting them to accept reading as part of their science teaching. The literature shows that teachers may be resistant due to time and school structure, so it is important that I incorporate as many of the conditions from the literature that support teachers changing their beliefs when planning my professional development model.

The Nature of Teacher Learning

The concept of teacher learning is complex, yet the one point that is agreed upon by scholars is that teacher learning is important and necessary (Feiman-Nemser, 2001). Teachers need opportunities to continue learning about teaching. Without access to extended learning opportunities, teachers will find it difficult to meet the challenges of educating students in a world that is continually changing with information and technology (Ball & Cohen, 1999; Fieman-Nemser, 2001).

Investigations into how teachers learn have been widely conducted. Emphasis has shifted from early process-product investigations (Shavelson, 1983) that tied teacher knowledge to how teachers managed, planned, organized, and evaluated to more recent research that investigates teachers' knowledge of their subject matter and their responses to students' understanding of that subject. There has been a move between looking at teacher thinking in context-free and context-rich environments: studies have gone from laboratory settings (Copeland, 1975) to actual classrooms of teachers (Dillon, O-Brien, Moje, 1994) trying to unravel the web of teacher knowledge. Contributions to the teacher knowledge literature come from many directions- cognitive psychology (Borko & Livingston, 1989; Chen & Rovegno, 2000), academe (Grossman,1990; Shulman,1986) , and teachers themselves (Codell, 1999; Paley, 1981, 2000). Each perspective brings its own epistemological underpinnings, adding to the complexity of what we know about how teachers learn best.

An examination of teacher knowledge by Cochran-Smith & Lytle (1999) provides a powerful framework for thinking about the development of teachers' knowledge. Cochran-Smith & Lytle categorize three ways that teachers acquire knowledge: Knowledge-for-practice, knowledge-in-practice, and knowledge-of-practice. Knowledge-for-practice assumes that there is a developed knowledge base of effective practices and teachers should learn these practices and then apply them to their classrooms. This type of learning is more formal and comes from that collective wisdom of professional knowledge that has been generated over the years. In contrast to knowledge that is out there to be acquired and applied, knowledge-in-practice describes knowledge that is constructed through the act of teaching. In this paradigm, knowledge is situational and teachers develop their teacher knowledge by reflecting on their practice. Knowledge- of-practice integrates ideas from the other two describing knowledge as constructed in a particular location, but relevant to others beyond the classroom, suggesting a collective undertaking of defining teacher knowledge between classroom teachers, the larger school community, and researchers alike. Cochran-Smith & Lytle's distinction between the three types of knowledge has been used to frame recent thinking about the relationship between theory and practice in teaching (Bondy & Brownell, 2004; McCleskey & Waldron, 2004).

In planning for this study, I will consider the Cochran-Smith and Lytle concept of knowledge-of-practice. This idea values the notion of knowledge as collective. It gives power to the teacher voice and the process of questioning, challenging, and adapting information to fit particular teaching contexts. These teachers continually question what they do along with the information they receive from others, recognized experts or not, to ensure they are creating and implementing practices that will help all their students succeed. Bondy & Brownell (2004) describe teachers who work in the knowledge-of-practice paradigm:

> For these teachers, knowledge is integrated, open to question, and often constructed with others. As such, knowledge generation for teaching is a collective and intellectual adventure that enriches teachers' abilities and understandings rather than simply improving their technique. (p. 50)

Even though I am presenting information to this group of science teachers in hopes of transforming their knowledge, it is through avid discussion and questioning that I want them to consider the worthiness and practicality of the ideas presented. The goal of this research is to understand how science teachers learn about the specialized discourse of science. Through the professional development medium, I hope to provide a context for stimulating conversation and analysis.

Characteristics of Effective Professional Development

Most often, the means of teacher learning for practicing teachers is through professional development. However, despite the general belief that professional development will transform teacher practice, many teachers view professional development as ineffective and an unproductive use of their time (Cohen & Hill, 2000; Kennedy, 1998). Professional development is typically delivered in a one-day staff development session to many teachers with the main goal of transmitting expert information to teachers, with the expectation they will transfer the knowledge to their classrooms (Fieman-Nemser, 2001; Garet et al., 2001). Secondary content teachers especially report discontent with this type of professional development in content reading, claiming that it is too generalized and does not offer content specific information (Campbell & Kmiecik, 2004; Daisey & Shroyer, 1993).

Recent research though offers insight into how to make professional development an effective process. The concept of inquiry based professional development is receiving much support (Richardson, 2003). Inquiry suggests that teachers should have active involvement in their learning process- asking questions, collaborating with peers, and deeply exploring new ideas and current practices (Darling-Hammond & McLaughlin, 1995; Fieman-Nemser, 2001; Richardson, 2003). Researchers are further recommending long-term professional development to assist and support teachers in making changes to their instructional practices (Anders, Hoffman, & Duffy, 2000). This can include coaching, observations, and follow-up sessions to analyze and critique practice (Darling-Hammond & McLaughlin, 1995; Guskey, 2002). Other significant characteristics cited are modeling of lessons and opportunities to practice the new ideas within the professional development setting (Fenstermacher, 1987).

In a large scale study on professional development, Garet, Porter, Desimone, Birman and Yoon (2001) identify characteristics of professional development that foster improvement. Garet et al. gathered data from surveys administered to over 1000 teachers who had participated in Eisenhower funded professional development. The authors distinguish three core features of professional development that contribute to its success: (1) focus on content knowledge; (2) opportunities for active learning; and (3) coherence with other learning activities. They also identify structural features of effective professional development including (1) reform-based; (2) duration; and (3) collective participation. Interestingly, Garet et al. found that the most important components to focus on were the three core features, duration, and collective participation. Traditional and reform-based structures of the same duration procured similar results in this study.

Similar results were achieved in a later study where researchers investigated the effects of different characteristics of professional development on how well teachers were able to implement an international science inquiry curriculum (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Penuel et al. collected data from 454 participating teachers. Researchers found that perceived coherence and time during professional development for planning implementation were significant to teacher learning. Teachers also reported greater change when their professional development involved collective participation. In this study, reform-like orientation was significant in teachers reporting change. However, Penuel et al. indicate a difference in how they define professional development structures from Garet et al. (2001): “We prefer to focus more on the design of the activities within type, acknowledging that a workshop can be designed using reform-oriented principles and a coaching relationship can be “traditional” (p.928). Reform-like orientation includes professional development that is highly focused on helping teachers prepare directly to make an impact on their practice. In this case, the support for integrating the program technology was also significant to how well teachers implemented the curriculum. This study is unique because it addresses teacher learning within the specific context of learning a science inquiry curriculum.

In addition to the large scale studies that identify characteristics of effective professional development, several smaller scale studies have yielded similar results. Particularly, two studies in content reading at the secondary level illuminate effective characteristics of professional development such as longevity and support. Dupuis, Askov, and Lee (1979) found that long term professional development had a positive effect on teachers’ willingness and ability to use reading strategies in their content classrooms. The Content Area Reading Project, a one year in-service program, was designed to change the attitudes and knowledge of junior high school teachers towards reading in the content area. Fifty-seven teachers participated. The in-service training involved bi-monthly field-based instruction by university personnel and on-site trained supervisors to support the daily incorporation of reading instruction. The researchers identified a comparison group for each site involving teachers who were working in the same school but not a party of the project. Both the experimental and comparison group were administered a pre and post attitude survey and project participants also completed a pre- and post skills test to measure acquisition of knowledge of reading instruction as well as final evaluations from the on-site supervisors about the observed changes in practice. Significant changes in attitude occurred for program participants. Smaller changes were seen in the scores for the skills test, but supervisor evaluations supported observed changes in teachers' instructional practices. Dupuis, Askov, & Lee recommend at least year long professional development and suggest that possibly even longer time may be needed to fully support changes in teaching practices.

In an in-service program implemented over two years, Wedman & Robinson (1988) achieved similar results. Fifty secondary content teachers participated in training to help content teachers incorporate reading strategies into their daily practice. Pre- and post tests showed significant changes in teachers' understanding of using reading in their content areas and their acceptance of their responsibility to use reading strategies.

Recent studies also find that effective professional development is content-focused (Brownell et al., 2008). In a professional development study designed to improve teachers' scientific knowledge, Rosebery et al. (1996) found that teachers gained a deeper understanding of science through extended opportunities and support to enact a new curriculum. Teachers participated in a summer workshop followed by a year-long seminar focused on improving scientific knowledge. Over the course of the year, discourse analysis revealed that teachers were using more scientific terms in their conversations and were more likely to try more progressive ideas on their classrooms.

In a study by Watson & Manning (2008), researchers engaged teachers in professional development to develop and improve their teaching skills in scientific inquiry. The professional development consisted of 20 hours of workshops broken down into 4 segments spread over several months. The format of each workshop involved an equal amount of time to 'expert input' where new ideas were presented to teachers and 'practice-based discussions' where teachers examined artifacts from their classrooms and reflected on using the new ideas in their classrooms. Teachers reported that the "expert study" part of the workshops helped to clarify the need and purpose for doing science inquiry whereas the 'practice-based discussions' were important for having concrete lessons and ideas to take back to their classrooms. While some teachers from this study did embrace the content and apply it to their classrooms, others were not as successful. From analysis of interviews, transcriptions form workshops, and portfolios, researchers found that two factors were especially powerful in accounting for the variability in teachers' learning. The first was teacher perception of the value of the workshop in addressing their needs and the second was the level of support teachers felt from their individual school in trying new ideas. These findings are consistent with other studies that show teacher perceptions and school support make a difference in transformation of teacher knowledge.

Findings from these studies clarify several features of effective professional development. First of all, time is important. Professional development needs to be continuous in order to give teachers an opportunity to interact with one another and the new ideas presented. In addition, teachers need on-going support and encouragement as they engage in infusing reading into their content classrooms. This support can come from peers, administration, or coaches. Professional development needs to build community. The environment of the learning needs to give teachers a chance to talk, reflect, and ask questions. Finally, effective professional development is content-focused, linking teacher, curriculum, and students together. The important features of professional development " . . . have more to do with guiding purposes and ideas, the pedagogy of the leader, norms of discourse that favor discovery, and connections to teachers context, content, and students" (Fieman-Nemser, 2001. p. 1047).

Summary

The literature presented in this chapter serves as a foundation to support the design and implementation of this study. This study will engage science teachers in learning about the specialized features of science language and applying what they learn to instructional practice through the context of professional development. This research is significant because it attends to calls from experts to discover ways that secondary teachers can improve the academic literacy of secondary students (Fang & Schleppegrell, 2008; Shanahan & Shanahan, 2008; Hand et al., 2003; NCTE, 2007). This study particularly will assist science teachers to better promote science literacy for all students. If teachers understand how language works in science, they can better instruct their students in how to comprehend challenging science texts and use language effectively to communicate scientific principles and understanding. This research is also significant because it applies current recommendations from the literature about how to plan effective professional development. This study addresses the concern of secondary teachers that professional development in secondary reading instruction is too generalized by designing science related activities for the professional development.

Information presented in this review supports the need for teachers to address the specialized language of science in secondary science teaching. The goal of improving science literacy for students permeates the literature (Fang, 2006; Norris & Phillips, 2001; Wellington & Osborne, 2001; Yore, Bisanz, & Hand, 2003). The studies on reading-science integration however establish that while research at the elementary level has been successful in showing the value of infusing reading with science instruction (Morrow, et al., 1997; Guthrie. et al. 2004; Romance & Vitale, 1995), little evidence is available for how this process of integration works in secondary education (Fang et al., 2008). It is crucial that research discovers how to best infuse reading into secondary science teaching and improve secondary students' science literacy.

The literature on teacher beliefs and professional development is valuable to this study because it clarifies the influence of beliefs on teacher learning and identifies the features of effective professional development. This literature demonstrated a need to create a safe, collaborative environment with opportunities for teachers to challenge and discuss their beliefs about reading and science learning. However, as Guskey (2002) identified, beliefs may not change until after teachers see that the teaching ideas make an impact on student learning.

In structuring the professional development for this study, the idea from the Watson and Manning (2008) article of "expert study' and "practice-based discussions" will be employed. This concept aligns with Cochran-Smith and Lytle's (1999) definition of teacher knowledge-of-practice. Knowledge is situational and teachers develop their teacher knowledge by reflecting on their practice. This is important because the goal of this research is to transform teachers' understanding of language and science and how it can influence their science teaching.

CHAPTER 3
RESEARCH METHODS

Scholars contend that teachers of secondary content areas must emphasize discipline-specific reading practices within their daily instructional routines if students are to improve their reading comprehension of subject related materials (Biancarosa & Snow, 2004; Heller & Greenleaf, 2007; Moje, 2008). In order for secondary teachers to change their instructional practices and adopt discipline-specific reading practices into their daily instructional routines, teachers themselves must examine their own knowledge and beliefs about reading and develop an understanding of how language is characteristically used to construct content in their subject areas.

The purpose of this study was to understand how secondary science teachers learn about the challenges presented to students by the specialized language of science texts. In this study, the term “science language” refers primarily to written science text. Through participation in professional development sessions, teachers examined the complexity of the language of science and considered various instructional techniques to help students overcome the comprehension challenges presented by scientific texts. By understanding how these science teachers learn about the specialized language of science, teacher educators and staff developers can better prepare science teachers to integrate discipline-specific language and literacy practices into their classroom instruction, with the ultimate aim of promoting the development of solid science literacy for all students.

Through qualitative study, researchers can discover the meaning individuals assign to particular experiences and move toward greater understanding of how the world works (Creswell, 2007; Patton, 2002; Strauss & Corbin, 1998). In this study, qualitative research offered a means for capturing the complexity and depth of the teachers' experiences (Creswell, 2007). The research questions necessitate a deep exploration of the participants' actions, interactions, responses, and questions as they participated in the sequence of professional development modules and implemented what they learned. A systematic analysis of the participants' experiences provided insight into how this particular group of teachers developed their understandings of the function of language in science text and translated that understanding into classroom practice. A detailed picture of the teachers' learning contributed to the understanding of how secondary science teachers acquire knowledge about the complexities of science language.

This chapter includes the research questions and theoretical framework for this study. Included also is an explanation of the research design including participants, site selection, data sources, and collection and data analysis methods. This chapter concludes with a discussion of the role of the researcher and trustworthiness of the research design.

Research Questions

Secondary subject texts are challenging to read. Each content area uses language in particular ways to construct discipline-specific knowledge and values (Fang & Schleppegrell, 2009). Secondary reading pedagogy needs to address these discipline-specific ways of using language (Moje, 2009; Olson & Truxaw, 2009). However, current efforts to infuse reading instruction in secondary content areas fail to address the discipline-specific reading demands and continue to focus on a set of basic, generalizable reading skills and strategies (Fang & Schleppegrell, 2009). In order to effectively teach students to read subject texts, content area teachers need to understand how language is characteristically used in their discipline. In this study, I investigated the influences on secondary science teachers' learning about the specialized language of science and the subsequent integration of that knowledge into their science teaching. The overarching research question for this study is: How do secondary science teachers learn about the specialized language of science and apply it to teaching reading of scientific texts? The specific questions guiding the study are:

- What do science teachers know about teaching reading in science?
- What understanding about the specialized language features of science do they construct through professional development?
- How do they integrate what they have learned about these specialized language features into their science teaching practices?

Addressing these questions contributes to a greater understanding of how secondary science teachers are enabled to examine new ways of integrating reading into their science teaching. The first question intended to tap the teachers' existing beliefs and knowledge about integrating reading into their science teaching. The second question aimed at capturing the teachers' thoughts and reactions as they learn about the specific language demands of secondary science texts. The final question brought to light the complexities involved in making pedagogical innovations as the teachers put into practice what they have learned about new ways of teaching reading in science. Taken together, the three research questions contributed to an in-depth understanding of how this group of secondary science teachers developed their understanding about the language of science. Through their participation in a professional learning community, the science teachers were able to examine the challenges presented to both teaching and learning by the complex nature of science language.

Theoretical Framework

Assumptions

Teacher learning is complex. In order to develop a rich, detailed picture of how science teachers learn about the specialized language of science, qualitative inquiry is an appropriate choice. Through a qualitative stance, I explored how these teachers made sense out of learning about the specialized language of science.

Choosing qualitative research presupposes several assumptions (Creswell, 2007). First of all, reality is accepted as subjective; multiple perspectives from participants are embraced and encouraged (Creswell, 2007; Patton, 2002). Next, qualitative researchers assume a place within the research setting, trying to get a better understanding through some level of interaction with the participants. Another assumption of qualitative research is that the research is value-laden (Creswell, 2007). Because of this belief, the researcher explicitly positions herself within the study reporting personal views, experiences, and biases that can influence the interpretation of the research. Creswell (2007) further notes that qualitative research assumes a certain rhetoric that encourages writing that is both personal and literary (p. 18). Finally, qualitative research assumes inductive logic to study a topic. The researcher listens, watches, and analyzes the research context with a flexible plan and a belief that theory and understanding will emerge as data are collected (Patton, 2002; Strauss & Corbin, 1998). These assumptions about qualitative research transcend the various approaches that different qualitative researchers employ (Creswell, 2007).

Research Paradigm

This study was shaped by Constructivism. Constructivism stems from the epistemological position that knowledge is formed through an individual's interaction with the environment (Crotty, 1998). Knowledge is not transmitted between sources, but negotiated and refined through the relationship of the individual and his surroundings. An individual constructs knowledge through personal experiences; therefore, knowledge and understanding are influenced by the historical and cultural norms of an individual's life situation (Creswell, 2007). Through interaction with the environment and others, individuals construct meaning and understanding about particular situations (Crotty, 1998). Because meaning is constructed, there is no "right" way to make sense of a particular situation. Utilizing a constructivist paradigm in this research allows a focus on participants' perspective on how understanding the specialized discourse of science is relevant to their teaching practices. Constructivism places value on each teacher's perspective and experience, realizing and accepting that individuals will have unique and distinctive responses to how they learn about a topic.

In this study, I was interested in how teachers learn and make sense of the specialized language of science and translate their understanding into classroom practices. Considering the multiple views of participants' experiences contributed to a better understanding of how knowledge of science language was formed and transformed during the professional development experience and how future professional development experiences can be designed to impact teacher learning.

Research Design

Setting

Green High School is a large public suburban high school located in northeast Florida that serves grades nine through twelve. The student population of nearly 3000 has an ethnic make-up of approximately 60% white, 26% black, 10% Hispanic, and 4% Asian/other. Twenty-two percent of the students are on free or reduced lunch. The high school is one of six county high schools in a school district serving around 32,000 students.

The town where the high school is situated has a population of roughly 9000 people with a median home cost of approximately $190,000. The primary sources of work in the area include retail trade, health care, construction, and recreation. In addition, Naval Air Station Jacksonville is located approximately three miles north of Orange Park and employs nearly 20,000 military and civilian personnel.

The administration at this school promotes teachers leaning about reading in the content areas. They have supported an after school reading learning community program that offers teachers an opportunity to do a small group study with other teachers about pertinent topics in education. Several texts that addressed secondary reading have been used in this setting including books by Chris Tovani, Janet Allen, and Kylene Beers. In addition, there is a reading specialist on staff who provides support to all the content teachers. She also has conducted workshops for the faculty addressing reading issues like fluency and vocabulary.

Participants

Selection of participants was based primarily on practical considerations such as willingness and access (Strauss & Corbin, 1998). The principal of a local high school willingly reviewed a brief description of the research project. During the pre-planning days of the 2008-2009 school year, the principal then convened a meeting of the 28 teachers in the science department. I attended the meeting and presented information about the study to the teachers.

In the meeting, I revealed the focus of the study on disciplinary literacy and emphasized the overarching goal to enhance secondary science teachers' expertise in reading instruction. An explanation of the structure and the time commitment was provided to the teachers. It was emphasized that participation involved approximately 15 hours of meetings after school and one hour of time each for individual interviews at the mid-term and ending points of the study. In addition, participation involved a minimum of 6 classroom observations. Seven science teachers chose to participate in the study.

In addition, participants were offered incentives to be a part of the project. Participation involved a significant amount of time after school as well as time in the classroom to implement ideas. Through a grant from The National Academy of Education, each participant was offered a $300 stipend as well as two books about science and literacy. Thus, participants in this study were motivated by the incentive as well as their own interest in exploring issues surrounding the integration of reading into secondary science curriculums.

Participants in this study involved six females and one male. All teachers were members of the same science department at this high school. The range of teaching experience was from five years to thirty-four and the grade levels taught spanned from ninth to twelfth grade. Further, participants represented various areas of science, including biology, anatomy, physical science, and marine science. Table 3.1 summarizes the demographic information of the participants.

The first participant was Bette. She had been teaching for five years. Bette came into teaching through an alternative program within the county. When she initially entered college she was a pre-med major. She earned her bachelors degree in biology with a minor in chemistry and Spanish. After graduation, Bette chose to pursue a career in teaching and completed her certification while in the classroom. She had experience teaching Earth/space science to eighth graders and high school biology. During this study, Bette taught five sections of honors biology to ninth and tenth grade students.

Prior to this study, Bette had participated in a year of workshops that met once a week to discuss best practices in education. This was part of her certification program. Bette stated that reading strategies were a part of the content covered during the workshops. Strategies that she recalled included jigsaw and vocabulary strategies. She said that her other source of information about how to teach reading in science was her fellow teachers. One of the teachers had shared the idea of using a logograph to teach vocabulary and she had adopted that into her teaching practice. She had not attended any workshops that specifically dealt with reading in science.

The next participant was Casey. Casey had been teaching for 15 years. She began teaching the Health Careers applied technology courses and did this for six years at another school before coming to her current position to teach science. She has taught health, biology, and anatomy and physiology. She taught at two high schools and was an adjunct professor at Florida Community College where she taught dental hygiene courses: Dental Radiology, Dental Materials, and Expanded Functions. Prior to becoming a high school teacher, she was a dental assistant for five years and a dental hygienist for 10 years. She completed a traditional four-year teaching program, graduating with a BAE in Health Education. She also holds an AS in Dental Hygiene. During this study she taught five sections of anatomy and physiology to tenth and eleventh graders.

Casey had participated in after school workshops that addressed reading. Workshop topics included fluency, vocabulary, and graphic organizers. She worked with the building reading specialist to implement a reading activity once a week for one month designed to promote fluency. She explained that she read a passage aloud and then the students read for one minute with a partner recording how far they got and then they calculated how many words they were reading per minute. In addition, Casey had read two recently published texts about reading: *I Read It, But I Don't Get It* by Chris Tovani and *When Kids Can't Read* by Kylene Beers. She had not attended any workshops that specifically dealt with reading in science.

Lisa was another participant. She had been teaching for 34 years in this high school. Her first teaching assignment was teaching science in a Catholic junior high in 1974. In 1976, she started work at Green High School. Lisa has taught a range of classes to tenth, eleventh, and twelfth graders including biology, severe learning disabled biology, marine biology I, marine biology II and physical science I. Lisa completed a four-year college program receiving a Bachelor of Science in secondary education with a concentration in biology and a minor in chemistry. During this study, Lisa taught five sections of marine science to eleventh and twelfth grade students.

Prior to this study, Lisa had participated in the after-school workshops facilitated by the reading specialist covering topics like fluency and vocabulary. She had participated in the learning community and read *I Read It, But I Don't Get It* by Chris Tovani and *Why Johnny Can't Read* by Rudolf Flesch. Lisa had approached the school advisory council about purchasing novels for the science classrooms and had just received multiple copies of books by Steve Alten such as *MEG: Primal Waters, Trench,* *the Loch, and Domain* and the book *Hot Zone* by Richard Preston to distribute to the science classes. She had not attended any workshops that specifically dealt with reading in science.

Mona also participated in the study. She had a combined total of 17 years of teaching experience. However, after her first 12 years of teaching, she took a break for 23 years and worked as a technical writer and a regulatory affairs specialist. She re-entered teaching five years ago. Her Bachelor of Science degree is in science education. During this study, Mona taught physical science to ninth grade students.

Mona did not have any prior experience with coursework or workshops that addressed reading in the content areas. She indicated that she followed the FCAT guidelines for doing reading in science and had consulted the Reading Essentials supplement to her physical science textbook, using a few activities. Mona had not read any recently published texts about reading in the content or received any particular information about science and reading. She had not attended any workshops that specifically dealt with reading in science.

The next participant was Billie. She had been teaching at this school for six years. Prior to teaching, Billie worked for the Department of Children and Families. She entered teaching through an alternative certification program, beginning a teaching job and earning her certification while in practice. During this study, Billie taught five sections of ninth grade physical science.

Billie had received information about reading in the content areas while she was participating in her certification program. Topics she recalled included note taking, graphic organizers, and vocabulary strategies. Billie said that she used guided reading worksheets to help her students read the textbook. Billie participated in the school based reading learning communities and had read three books: *I Read It, But I Don't Get It* by Chris Tovani and *When Kids Can't Read* by Kylene Beers and *Building Background Knowledge* by Robert Marzano. She had not attended any workshops that specifically dealt with reading in science.

The next participant was Brad. Brad had been teaching for eight years, one year in middle school and seven years at the high school level. He had spent one year in a private high school. Brad has taught all levels of biology, anatomy, environmental physics and medical skills. This was his first year at this high school. Prior to teaching, Brad worked in a pharmacy for six years and attended pharmacy school. However, he did not complete his studies and chose to pursue a career in teaching science. Brad earned a Bachelor of Science in biology with a minor in education. During this study, he taught five sections of biology to tenth graders.

Brad had participated in one workshop that addressed reading in the content areas in 2004. This workshop was facilitated by McRel, a private, nonprofit corporation that contracts to deliver professional development to schools. Brad said he received a book that addressed reading strategies for vocabulary like graphic organizers. In the workshop Brad said they reviewed several of the strategies in the book and showed participants how to use the book. He said he did use several of the ideas such as graphic organizers and strategies for accessing prior knowledge. Brad had not attended any workshops however that specifically dealt with reading in science.

The final participant was Patsy. Patsy taught for 12 years. She started teaching at the junior high level for three years and then moved to the high school level. She had experience teaching a variety of classes including physical science, biology I, biology I honors, Earth/space science, and advanced placement biology. Prior to teaching she worked as a research specialist for five years at UF – Shands Jacksonville Health Science Library where managed their journal collection, performed online computer searches for the medical staff at UF Shands-Jacksonville Hospital, obtaining interlibrary loan articles for medical staff, and filed state travel claims for library supervisors/director. Bette also served as the sole Medical Librarian for the newly formed Humana Hospital library for one year where she managed a team of medical doctors for the Library Procurement Committee. Patsy held a Bachelor of Science degree in Psychobiology from UCLA. She earned 19 graduate hours from JU to obtain her teaching certificate and also held National Board Certification in adolescent and young adult science with a specialty in biology. During this study, Patsy taught three sections of honors biology to tenth graders and two sections of Advanced Placement biology to eleventh graders.

Patsy had read *I Read It But I Don't Get It* by Chris Tovani and *Yellow Brick Roads* by Janet Allen during her participation in a school based reading learning community. In these workshops the group did a book study and discussed best practices in teaching. Patsy incorporated the idea of using logograph to teach vocabulary in her classroom from the texts she read. Patsy also indicated that she read information about science literacy while preparing for her National Board portfolio. She had not attended any workshops however that specifically dealt with reading in science.

Process

In this section, the process of designing the professional development effort will be briefly described. Chapter 4 will elaborate on the particular aspects of the professional development design.

Research upholds that it is effective for teachers from the same school to collaborate in a content- focused professional development program (Darling-Hammond & McLaughlin, 1995; Fieman-Nemser, 2001; Richardson, 2003). Research further supports involving teachers in long-term professional development to provide sustained opportunities for reflective thinking about their teaching practices (Glasson & Lalik, 1993; Guskey, 2002; Wedman & Robinson, 1988). This process is especially important in convincing secondary teachers to embrace teaching reading in their content areas because of the documented resistance to and lack of support for reading infusion in secondary content area classrooms (O'Brien, Stewart, & Moje, 1995)

The goal for this study was to examine how secondary science teachers' from varied backgrounds learn about the specialized features of science language and integrate the ideas into their teaching practice. Research supported the use of the medium of a professional development program in order to investigate this experience. The professional development plan encouraged the science teachers' exploration of pertinent topics related to the functional analysis of science language.

The researcher designed a series of workshops that provided teachers with an opportunity to examine how language functioned in science to develop theories, concepts, and ideas. In this study, seven science teachers participated in monthly meetings with the researcher from August 2008 through April 2009. The purpose of this professional development effort was for teachers to develop their understanding of the language demands of science reading and strategies for coping with these reading challenges.

Experts contend that there are many features of scientific language that make it distinctive from other content areas such as history or math (Fang, 2006; Fang & Schleppegrell, 2009). These features include the large amount of technical terms, the abstract words developed to explain theories, the large amount of information packed into sentence that make the writing dense, and the complex organizational patterns that scientists use to explain scientific phenomena. These features of science language served as themes for the professional development sessions. Following is a list of the topics covered in each session of the professional development effort.

- Module 1: Unique linguistic challenges of secondary science reading
- Module 2: The *technicality* of science language and coping strategies
- Module 3: The *abstractness* of science language and coping strategies
- Module 4: The *density* of science language and coping strategies
- Module 5: The *genres* of science language and coping strategies

In between meetings, the researcher visited the classroom weekly offering support through informal observations and conversations. This ongoing cycle of meeting, trying out new ideas and talking about the challenges and successes of implementing these ideas engaged teachers in reflective thinking about how their understanding of how language is used in science contributed to their teaching practice.

Professional development sessions included examination of relevant journal articles and book chapters as well as presentations about the specialized features of science language. In addition, teachers brought science textbooks and other sources of classroom reading materials to each session in order to analyze the ways language was used in these texts, discuss the challenges scientific language may present to students, and consider strategies for coping with these language demands.

In addition to these professional development modules, the researcher conducted an initial session to assess the teachers' knowledge and beliefs about teaching reading in science and a post session to collect a summative response to the entire professional development experience. Chapter 4 details the context and content of the professional development effort.

Data Collection

Data are an important part of the research process because it is from data that theory and knowledge are constructed (Strauss & Corbin, 1998). Creswell (2007) refers to data collection as a process involving the following activities: locating a research site, gaining access and establishing rapport, purposeful sampling, collecting data, recording information, resolving field issues, and storing data. In order to conduct this study, permission to access a site was gained through the approval of an Institutional Review Board at The University of Florida. Next, I contacted a local high school principal and presented information about the study to 28 members of the science department. The principal visited the meeting and encouraged members of her science department to participate in the study. Once the site and participants were confirmed, a letter was sent to participants explaining the research process and requesting their permission for involvement as well as a copy of the IRB (Appendix A). Convenience sampling was used to acquire participants from a willing pool of 14 teachers who showed interest in the study.

In this study, a variety of data sources were used to gather information to help explain how secondary science teachers learn about the specialized language of science. The primary source of data in this study was transcripts of professional development sessions and individual interviews with participants. Secondary data sources included informal classroom observations and follow-up conversations with teachers, email communications, and concept maps. Data consisted of approximately 25 hours of audio-recordings which documented 14 hours of professional development sessions, 7 hours of interviews, 2 hours of informal conversations, and 2 hours of classroom interactions. In addition, there were over 70 pages of field notes from participant-observations and nearly 500 pages of transcription.

Documents

Teachers completed an initial written survey to capture their knowledge, beliefs, and prior experiences with reading in science (Appendix B).

Interviews

Teachers participated in two semi-structured interviews during the research process. Duration of the interviews was between 20 and 30 minutes. Each interview was recorded with a digital-voice recorder and then transcribed. Interview questions were developed based on information that was presented in the professional development sessions. A mid-term interview was conducted to assess teachers' views and understanding of the content of the professional development. (Appendix C). A final interview further assessed what the teachers learned from their experience and probed for how they will continue to implement and develop their learning about the specialized language of science (Appendix D). The interviews provided insight on what influenced the learning process of individual teachers.

Informal Contact

Throughout the duration of the research, informal conversations with individual teachers provided feedback about their understanding and experience teaching about the specialized language of science. I recorded field notes about the content of these conversations in a research log. This information provided insight into the successes and barriers teachers encountered as they attempted to integrate the new ideas into their daily teaching routines

Participant Observations

Participant-observation served as a secondary resource in this study. Observation of the teachers in the classroom demonstrated if there was consistency between what teachers said about their classrooms in the professional development session and what was actually happening. In addition, observations showed how and if teachers were implementing any of the strategies addressed in the professional development meetings. Finally, being a part of the classroom shed light on the teachers' daily routines. In addition, I could provide constructive feedback about integrating reading into their current teaching practices. Table 3.2 provides a chronological listing of the observations completed during this study.

Classroom observations took place on a weekly basis contingent upon a mutually agreed upon time by the teacher and the researcher. Observations lasted for at least 30 minutes. DeWalt &DeWalt (2002) believe that the role of a participant- observer can be varied in the level of involvement. Since the purpose of the observation was to collect data about the teachers' use of strategies and concepts in the classroom, researcher participation on most occasions was relatively low. Unless prompted by questions from the teacher, the researcher's role was to watch and listen. However, in some cases, teachers requested to see a model lesson or team teach a lesson.

Detailed field notes were recorded through long-hand during observations. The observation protocol included both descriptive and reflective notes. (Appendix E). In the descriptive column I recorded information about observed classroom activities that involved reading or attended directly to a strategy discussed in professional development sessions. In the reflective column, I recorded wonderings and thoughts about what was happening in the classroom as it pertained to the research study. Topics considered in reflection were how issues identified in the literature such as class size, class behavior, structure of the school day, and pressure from state testing impacted the teachers' implementation process.

The following questions were informally discussed after observations: What do you think went well with your lesson? What would you do differently if you tried this again?

Data Analysis

Data was analyzed using methods characteristic to grounded theory studies (Creswell, 2007; Strauss & Corbin, 1998). The process of grounded theory allows the researcher to interact with the data and extract a theory directly from the raw data (Crotty, 1998). The purpose of this analysis was to identify themes from the data and generate a theory about the participants' process of learning about the language of science. The constructivist theoretical framework lens to this grounded theory study allowed the researcher to consider how the participants' ideas, views, feelings, assumptions, beliefs, and experiences contributed to the overall learning process of this group of science teachers.

Grounded theory provides a systematic way of realizing the interplay between the researcher and the data (Strauss & Corbin, 1998, p. 13). For this study, grounded theory is an appropriate choice because it provided a systematic means of making sense out of the interactions between the teachers' participation in the professional development and the integration of the ideas in their classrooms. Grounded theory analysis allowed categories to emerge and scaffold into a working theory about how science teachers come to apply their understanding of the language demands of scientific language to their teaching practice. In this study, the process of data analysis involved repeated readings, codings, and comparisons of data sources (Creswell, 2007; Glaser & Strauss 1967; Strauss & Corbin, 1998). Applying the techniques of coding and constant-comparison allowed the researcher to build a theory of what facilitated and inhibited the learning of secondary science teachers in this study.

To analyze the data, the process of coding was employed. Strauss & Corbin (1998) describe this process as both "fluid and dynamic," allowing the researcher to discover categories, relate categories, and finally organize the categories in order to create a theory. There are three stages in the process of coding: open coding, axial coding, and selective coding. The first stage of open coding involved examination of the data for preliminary categories and variables that emerged to explain how the teachers make sense out of the information presented in the workshops (Strauss & Corbin, 1998). The researcher started the process by using line-by-line analysis to look at the interview and professional development transcripts. Initial analysis involved searching for themes and categories in the teachers' sense making (e.g., barriers, struggles, excitement, insights, resistance, issues, and concerns). Examples of codes at this point included: blame on student behavior, reluctance to incorporate reading, networking, doubting. This stage allowed the researcher to reduce large amounts of data to more manageable parts. Prevailing categories emerged based on like features and properties allowing the researcher to place the data along dimensions.

In addition to the open coding, the researcher used memoing at this point to record responses about the ongoing analysis and reflect on the secondary data sources (i.e. field notes, email communications, researcher's log). Memoing is the process of writing down notes about the evolving theory (Creswell, 2007). This technique was particularly useful because it helped the researcher to keep track of her own thoughts, questions, and changes in ideas as the research progressed.

The next stage of analysis involved axial coding which adds "depth and structure" to the analysis (Strauss & Corbin, 1998). The goal at this stage is to discover relationships and connections between the categories as the researcher works to put the data back together in a new way. Answering questions at this point like how did teachers use the techniques in their classroom? provided insight into the relationship between the teachers' report of their understanding of a concept like abstraction and their actual application of it in the classroom. Using an organizational tool like the paradigm described by Strauss and Corbin (1998) allows the researcher to create categories around the conditions, actions, and consequences that are significant to the phenomenon being studied and essentially build a theory. At this stage, data was analyzed for links between categories that might aid in conceptualizing what conditions might best lend to a teacher embracing and implementing the strategies presented about the specialized language of science. Examples of codes at this point included:

feedback from instructor, peer interactions, and time for expert review. Initial codes were collapsed into larger categories and analysis of the data continued looking for evidence of support for the axial codes. At this stage, the open and axial coding happened simultaneously.

The last stage of coding was selective coding. Selective coding is “the process of integrating and refining theory” (Strauss & Corbin, 1998, p. 143). The goal at this stage was to identify a central category and an explanation for how the sub-categories fit together within that category. In this study, central themes emerged connecting the major categories identified in the analysis procedures to explain how secondary science teachers learn about the specialized features of science language. The core theme in this study was the factor of *opportunity to talk*. Through data analysis it was revealed that this was the most salient factor in teachers’ learning process. Memos and all data analysis up to this point contributed to the identification of the selective codes.

In this study, data was analyzed both within cases and across cases. Findings from within case analysis identified the experiences of each science teacher. Cross-case analysis was then used to analyze data along the lines of themes such as technicality, abstraction, density, and genres. This analysis procedure contributed to the development of a theory about how the teachers’ conceptualized and interpreted the specialized language of science and related it to their practice of teaching science. The analysis procedures in this study were on-going and iterative throughout the data collection period. The systematic coding process allowed identification of themes and categories to build a theory about how this group of science teachers’ learned about the specialized language of science and integrated it into their teaching practice.

Validation Strategies

Qualitative research strives to accurately represent the experiences and stories of the research participants. It is important that the researcher uses various techniques for assessing the accuracy of the findings (Creswell, 2007). Other terms that have been used in qualitative research to try and capture the essence of "getting it right" in qualitative research include "trustworthiness" (Angen, 2000), "credibility" and "authenticity" (Lincoln & Guba, 1985).

One strategy for establishing validity is through spending time in the field with participants (Creswell, 2007). Extended exposure to participants through observations and interaction allows the research to build trust and understanding of the research environment. I spent 6 months working with the science teachers in this study. Between weekly classroom visits, tri-weekly meetings, interviews, and informal conversations, a relationship was established with the participants that encouraged their candid and honest responses.

A common technique used in qualitative study to establish validity is thick description of the study setting and participants (Creswell, 2007). This is important because it allows others who read the research to evaluate how and if the results can transfer to their own situations. A vivid, rich description of the details of the participants and their interactions during professional development was provided in this study.

Another strategy employed was identifying researcher bias. This is important because it clarifies how the researcher's experiences influence motivation and interpretations of events. I included a reflection on my experiences in order to establish researcher bias.

Member checking was also employed to validate this study. Member checking involves asking the research participants to review the researcher's conclusions and interpretations (Creswell, 2007; Lincoln & Guba, 1985). At the beginning of each session, interpretations of the teachers' experiences were reviewed and examined. In addition participants were offered an opportunity to respond to the themes and descriptions of their participation in the professional development sessions during individual interviews. Further, transcribed interviews were sent to the teachers for review and feedback.

Role of the Researcher

Subjectivity

I am trained as a reading specialist and have taught reading and language arts from grades 6-12. My experiences are widely varied in settings from a suburban middle school setting in Columbus, Ohio, to a city high school setting in Duval County Florida, and an inner-city middle school in Baltimore City. In addition, I taught for two years at a high school in the county where I conducted this research.

Two experiences particularly shaped my interest in secondary content reading. In my position as a mentor-liaison with the Johns Hopkins University, I was afforded the opportunity to work directly with middle school teachers from all content areas in implementing best practices in reading into the teaching routines. I taught onsite courses, conducted monthly-staff developments, and participated in individual teachers' classrooms by modeling and co-teaching lessons. Informal feedback from teachers who embraced the ideas shared through these experiences motivated me to find more avenues for reaching out to secondary content teachers.

The next experience that shaped my passion for secondary reading was my role as a reading fellow on a grant at the University of Florida. Through closely working with two middle school science teachers, I was able to see the transformation in their teaching. As a reading fellow, I collaborated with the teachers on weekly reading lessons, observed the daily classroom practice, and modeled lessons in their classrooms. The end of the project led to positive changes in student performance and did convince the teachers to integrate reading into their science instruction. In fact, the teachers even presented information from our project to their fellow teachers in the district, further motivating me to replicate this experience with other secondary area content teachers. These experiences definitely shaped my role as a researcher and warrant disclosure to research participants.

The role of language in learning has always been of interest to me. As a language arts teacher, I was continually challenging my students to consider how language functions to communicate ideas. From analyzing texts to producing writing, I maintained a focus in my teaching on language. In a presentation at NCTE I paired with a colleague to share strategies to use in the secondary English classroom to encourage students to think about language. One strategy we advocated was to view different broadcasts of the same event and consider how the speakers both used language uniquely to express contrasting viewpoints about a topic. My interest in language as a central part of learning language arts translated easily into seeing language as important in understanding science. Through several courses during my doctoral program at the University of Florida, I came to understand more clearly how scientists use language in science. It made sense to think about the various genres in science and how their organization offers some predictability in the reading of science. I came to see that if I understand how scientists organize and use language to express ideas, I can improve my comprehension of science material. This belief in helping my own understanding of science led me to believe that if we can work with students to see more explicitly how language is used as a tool, this may improve not only their understanding of science, but possibly their interest too.

Despite my knowledge of reading, however, I do not consider myself an expert in teaching science. Though I have worked closely with science teachers in various settings, I have not taught science. The content, especially of some of the more advanced levels of science like physics and anatomy, is challenging to me. It is for this reason that I am interested in working closely with science teachers to see if we can inform one another's instructional practices through our joint effort to promote scientific literacy for all students.

Trustworthiness

In order to establish trustworthiness with this group of seven science teachers, it was important to share my assumptions, beliefs, and experiences with the participants at the onset of this study (Lincoln & Guba, 1985). During our first session, we had an open discussion to learn more about one another. Sharing my experiences helped to develop a rapport with teachers so that they felt comfortable sharing their stories and ideas with me (Creswell, 2007).

Responsibility

Many qualitative researchers are participant-observers to a range of degrees in studies. In this study, my degree of participation was high since I facilitated the professional development effort as well as the classroom observations. As a facilitator, I planned the professional development sessions including the session format and the materials used. My role as the facilitator was to prompt the participants' thinking about the specialized discourse of science and what it means to their teaching practice. The sessions involved opportunities for participants to shape the conversation and ask relevant questions about the topics covered. As a facilitator, I also modeled sample teaching lessons and prompted teachers to analyze the validity and usefulness of the strategy to their teaching.

In addition to facilitating the professional development sessions, I served the role of participant-observer in the teachers' classrooms. If the teacher invited me to co-teach or model a lesson in the classroom, then I participated in the class. This role allowed me the flexibility to respond to each individual teacher's comfort level with the process of learning about the specialized discourse of science.

My role in this research is somewhat complicated because I want to convince the participants to change their teaching practice to include explicit instruction in the specialized discourse of science. As a reading specialist, I believe that reading should be a practiced skill in secondary content classrooms. Students could enhance their content learning by reading a variety of texts, informational and narrative. In addition, the secondary content teacher should have the knowledge to assist students in comprehension of content area texts.

However, as a researcher, I acknowledge the constraints and difficulties of doing this in the secondary setting. Often the teachers do not have a variety of reading materials at their disposal, nor have they been provided with enough information and support to try the new instructional practices. I believe that efforts need to be made to discover how secondary content teachers can best integrate reading instruction into their daily instructional routines, hence the development of this study.

Summary

This study documents the experience of seven secondary science teachers as they participated in learning about how language functions in science. Through their participation in a professional development program, teachers examined the complexities of science language and integrated new strategies for addressing these complexities into their classroom. The details of the professional development effort are described in Chapter 4. Chapters 5-7 report the findings and the grounded theory about how secondary science teachers learn about the specialized features of science language. Included in the findings are excerpts from teachers' interviews and conversation during professional development sessions to show how the teachers' explored and learned about the language of science and strategies for use in their classrooms.

Table 3-1. Teacher Information

Name	Gender	Age	Teaching Experience (Years)	Teacher preparation	Courses Taught	Grades Taught
Bette	Female	30	5	Alternative	Biology honors	9th 10th
Casey	Female	53	15	Traditional	Anatomy and physiology	10th 11th
Lisa	Female	56	34	Traditional	Marine science	11th 12th
Mona	Female	55	17	Traditional	Physical science	9th
Billie	Female	28	6	Alternative	Physical science	9th
Brad	Male	35	8	Traditional	Biology	10th
Patsy	Female	53	12	Alternative	Biology honors	10th 11th

Table 3-2. Chronological List of Observations

Date	Teacher	Topic	Time (Minutes)
9-08-08	Mona	Initial	50
9-08-08	Brad	Initial	50
9-08-08	Lisa	Initial	50
9-09-08	Bette	Initial	50
9-09-08	Billie	Initial	50
9-11-08	Casey	Initial	50
9-15-08	Patsy	Initial	50
9-23-08	Brad	Active Reading	50
9-23-08	Casey	Active Reading	50
9-29-08	Lisa	Active Reading	50
9-29-08	Bette	Active Reading	50
9-30-08	Billie	Active Reading	50
10-01-08	Mona	Active Reading	50
10-01-08	Patsy	Active Reading	50
10-20-08	Lisa	Technicality	30
10-20-08	Bette	Technicality	40
10-21-08	Mona	Technicality	40
10-21-08	Patsy	Technicality	50
10-21-08	Brad	Technicality*	50
10-27-08	Billie	Technicality	40
10-27-08	Casey	Technicality	30
10-28-08	Patsy	Technicality	50
10-28-08	Brad	Technicality*	40
11-12-08	Brad	Abstraction*	40
11-13-08	Casey	Abstraction	30
11-17-08	Billie	Abstraction*`	40
11-18-08	Brad	Abstraction	40
11-19-08	Patsy	Abstraction	50
11-19-08	Bette`	Abstraction*	50
11-19-08	Lisa	Abstraction	30
12-01-08	Mona	Abstraction	40
12-10-08	Mona	Abstraction	20
1-21-08	Billie	Density	30
1-26-08	Casey	Density	30
1-27-08	Bette	Density*	40
1-27-08	Brad	Density	40
1-27-08	Lisa	Density	50
128-08	Mona	Density	30
3-2-08	Bette	Genres	50
3-2-08	Casey	Genres	30
3-2-08	Lisa	Genres	30
3-5-08	Mona	Genres	50
3-09-08	Patsy	Genres	50
3-09-08	Brad	Genres	30

CHAPTER 4
PROFESSIONAL DEVELOPMENT MODULES

The purpose of Chapter 4 is to describe the design of the professional development modules utilized for this study. This chapter includes a detailed description of the content and context of each module.

The following three sections outline the components of the professional development modules. The first section explains the contextual features of the professional development sessions. The next section describes the schedule, duration, format, and organization of the modules. The final section includes a detailed account of the content of each of the eight modules designed to promote teacher learning about science language.

Context

Garet et al. (2001) identified three core features of effective professional development: (a) focus on content, (b) promotes active learning, and (c) fosters coherence. Each core feature was addressed as follows in this study.

Focus on Content

There is growing support that high-quality professional development efforts encompass a strong focus on content (Brownell et al., 2008; Garet et al., 2001). In this study, the goal was to transform teachers' understanding of the role of the specialized language of science in reading science text. Therefore, the professional development sessions included science content with an emphasis on content-specific reading skills in science. The professional development sessions supported teachers in developing an understanding of the specialized language of science and strategies for applying that information to their own instructional routines.

Promoting Active Learning

There is agreement in the professional development literature that teachers need to be actively involved in learning during the professional development experience (Desimone, Birman, & Yoon, 2001; Garet et al., 2001). In order to promote active learning in this study, sufficient time was provided during the professional development modules for teachers to plan for instruction and discuss the efficacy of the strategies presented by the facilitator. Follow-up classroom visits by the facilitator further promoted the actual implementation of their learning and opportunity to reflect on their teaching. Also, teachers were continually encouraged to share what they learned with colleagues and one another.

Fostering Coherence

Teachers want to see how what they learn about in professional development links to broader goals and missions of the field (Garet et al., 2001; Penuel et al., 2007). In this study, direct connections between the information presented about the specialized language of science and the types of science reading that the general population is expected to be able to do were addressed. In addition, recommendations from national organizations like The National Council of Teachers of English (NCTE), the National Research Council (NRC), and National Science Teachers Association (NSTA) were reviewed and discussed during the professional development sessions.

Duration

This research study occurred over a 7 month period, beginning in September 2008 and concluding in April 2009. Table 4.1 outlines the schedule of the professional development meetings. The professional development modules took place approximately once every three to four weeks for a total of 8 meetings. Each session included a two-hour formal session where professional readings were discussed and a brief presentation of strategies that could be applied in the classroom were presented to the whole group. This was then followed up by individual teachers planning for implementation in the classroom. The following section of this paper will detail the format of the professional development modules.

Format

Experts contend that traditional means of delivering professional development are no longer viable (Brownell et al., 2008; Garet et al., 2001; Guskey, 2002). Single sessions or one-day formats focused on transmitting information to teachers with the expectation they will take it back into their classrooms has not proven to be effective. Recent literature on professional development advocates for formats that encourage collaboration and reflection among participants and provide opportunities for participants to actively participate in integrating new ideas into their teaching (Desimone, Birman, & Yoon, 2001).

The structure of each session was broken down into an hour of expert review and an hour of practice-based discussion (Watson & Manning, 2008). The first hour of each session was dedicated to the expert study. Components of expert study included professional readings and modeling of strategies. Teachers were encouraged to question, analyze, and weigh the information presented against their own experiences in order to develop their understanding of the specialized language of science.

The second hour was dedicated to practice-based discussions. In this segment of time, teachers were able to analyze the usefulness of the strategies. They could use their own materials to plan for classroom implementation and reflect on the plausibility of using the information from the expert study in their own classrooms. This segment supports the call for effective professional development to involve teachers actively in the learning process (Desimone, Birman, & Yoon, 2001). Additionally, in each module, topic relevant questions were posed at the beginning and end of the meeting to prompt thinking and conversation.

The following section addresses the specific content of the professional development modules. Details of topics covered, titles of readings, and specific questions asked of participants are described.

Content of Modules

There were a total of eight modules in this professional development plan. The first module was the initial meeting entitled pre-professional development. The next five modules addresses the topics covered associated with science language. Included in this series of modules was a midterm and post module to review and check for understanding.

Module 1

- Date. September 2008
- Title. Pre-Professional Development Module.
- Objective. Teachers will complete personal statements and participate in discussion about prior beliefs, knowledge, and experiences with secondary content reading in order to collect baseline data.
- Details: This session opened with introductions and a general overview of the purpose and schedule of the research project. Teachers were then asked to complete a personal statement to assess prior knowledge about reading. Information gleaned included teaching history, current teaching schedules, and eight questions about reading in science (appendix B).

  Questions to probe teachers' thinking about reading in science included:

- What role, if any, has reading played in your personal endeavor to learn science?
- What role, if any, does reading play in learning science?

- What are some similarities between learning science and learning other subject areas?
- What are some differences between reading science and reading other subject areas?
- What reading skills do students need to access scientific texts successfully?
- What issues do your students confront in accessing scientific texts and how do you address these issues in your teaching?
- What would you hope to learn in this professional development effort about helping students with science texts?
- Tell me about the reading materials available to use in your classroom.

Once personal statements were completed, questions from the personal statement were posed by the instructor and participants shared and discussed their answers. This conversation was important to establish community and cohesiveness in the group. Teachers willingly participated in this activity.

After the discussion, teachers were asked to complete a semantic map representing the skills each teacher believed students needed in order to read scientific texts. The maps were then collected and held until the final meeting so teachers could then revisit and revise their maps based on new information from the professional development experience. The information gathered from the personal statements and the semantic maps was further used to shape and refine subsequent professional development modules.

Module 2

- Date September 2008
- Title. The Unique Language Demands of Science Reading
- Objective Teachers will read from selected texts in order to compare the differences between science reading and other types of expected school reading.

- Details. In this session the “expert-review” and “practice –based” model began.
- The session opened with a brief explanation of the organizational structure of the next five modules.

The following question was posed to begin discussion:

- What are some of the challenges involved in reading a science textbook when compared to reading a Harry Potter book?

Participants spent 10 minutes discussing the question. Answers were recorded in a two-column chart on the board.

Expert review

This time was dedicated to reading several segments from *Language and Literacy in Science Education* by Wellington and Osborne (2001). Discussion opened with a preview of the text where participants looked at chapter titles, tables, and diagrams. The facilitator then summarized the text explaining that the authors contend that language is one of the main barriers to students’ learning of science and throughout the text the authors call attention to the role of the teacher in supporting students’ improvement in science learning through an emphasis on language.

Participants were then directed to Chapter 4 to examine the opening quote: “Since reading is a major strategy for learning in virtually every aspect of education . . . it is the responsibility of every teacher to develop it” (Bullock, 1975 in Wellington & Osborne, 2004, p. 41). After a brief discussion, the facilitator and participants read aloud chapter 4 entitled “Learning from reading.” In this chapter, Wellington and Osborne offer explicit strategies for helping students deal with the demands of science reading. Discussion was led by the teachers’ responses to the reading.

Practice based discussion

In the second section of this module participants were asked to read the article by Fang (2008), entitled "Going beyond the Fab Five: Helping students cope with the unique linguistic challenges of expository reading in intermediate grades." In this article, Fang argues that current instruction in reading does not address the unique demands of expository texts. He provides sample texts to show the differences in reading demands between a typical narrative text used in school and an expository science text. Further, Fang highlights four features of expository text (i.e. technicality, density, abstraction, authoritativeness) that impact student comprehension and explains classroom strategies to assist students with reading expository texts. This article reinforces the ideas presented in Reading in Secondary Content Areas: A language based pedagogy (Fang & Schleppegrell, 2009).

This article served as a springboard into the next sessions because it offered a brief overview of the issues of technicality, density, abstractness, and complexity. Teachers worked in pairs to scan their textbooks for samples of each of the four features of expository text discussed in the article.

Closure

In closing, the following questions were posed:

- How do you think this information relates to your teaching of science?
- What are your concerns about trying the strategies presented in this article with your students?

Assignment

In preparation for classroom visits for the week, participants were instructed to do something they would typically do with reading in their classrooms. In addition, participants were encouraged to conduct an informal survey with their kids about their opinions of reading science. Teachers were also encouraged to read chapter one and two from *Reading in Secondary Content Areas* (Fang & Shleppegrell, 2008). Chapter 1 of this text sets up the current issues with reading in the content areas in secondary settings and introduces the idea of functional language analysis as a means of addressing problems teachers encounter when using reading in their content classrooms. Chapter 2 then explains the complexity of science language describing how it is simultaneously technical, abstract, and dense and how to apply functional analysis strategies in the classroom.

Module 3

- Date. October 2008
- Title. The technicality of science and coping strategies.
- Objective. Teachers will understand how science reading is technical by examining sample texts and participating in model classroom lessons.
- Details. This session opened with sharing information from the informal survey participants conducted with students about science reading.

Expert review

In this session, the expert review involved reviewing how science language was technical. Participants were led through a review of the section on technicality from the Fang (2008) article previously read. In addition, participants reviewed the portion of Chapter 2 from Fang and Schleppegrell (2008) [pages 18-22] that covered technicality. Participants were asked to read silently and then view a power point presentation about technicality in science language.

Practice based discussion

In the second portion of the session, participants explored strategies for coping with technicality. Participants reviewed Chapter 4 of Fang, Lamme, and Pringle (2009) which provided explicit examples of how to employ language analysis strategies in the classroom. The instructor then modeled strategies for the participants. The following strategies were included: morphemic analysis, vocabulary think charts, and concept definition word maps. Participants discussed how they might integrate these strategies into their own teaching.

Closure

The following questions were posed:

- How do you think this information relates to your teaching of science?
- What are your concerns about using this with your students?

Assignment

Develop a lesson plan using one of the strategies discussed in class. Bring samples and response to our next session.

Module 4

- Date. November 2008
- Title. The abstractness of science language and coping strategies.
- Objective. Teachers will understand how science reading is abstract by examining sample texts and participating in model classroom lesson.
- Discussion opened with the following questions:
- Explain in what way the technicality of science present reading challenges to students.
- How did you use your understanding of technicality to help your students read in your science teaching?

- Describe how your students responded to your lessons that addressed technicality in science language.

Expert review

In this session, participants were introduced in greater detail to the concept of abstractness in science language. A power point presentation reviewed key components of how science language is abstract. In addition, participants revisited the section about abstraction in science language from *Reading in Secondary Content Areas: A language based pedagogy* (Fang & Schleppegrell, 2009).

Practice based discussion

In the second portion of the session, teachers explored strategies for coping with abstraction. Chapter 4 of Fang, Lamme, and Pringle (2009) provided examples of classroom strategies for addressing the issue of abstraction. Strategies modeled in this section included: sentence completion and paraphrase. Participants discussed how they might integrate these strategies into their own teaching. The teachers discussed how to apply what they learned about the abstractness of science discourse to their own practice by reviewing their curriculum materials and searching for ways to integrate the strategies into their daily plans.

Closure

The following questions were posed:

- How do you think this information relates to your teaching of science?
- What are your concerns about using this with your students?

Assignment.

Develop a lesson plan using one of the strategies discussed in class. Bring samples and response to our next session.

Module 5

- Date December 2008
- Title Midterm Review (This session was one hour in length)
- Objective. Teachers will review information from the first modules.

The session opened with discussion on the lesson teachers did on abstraction.

The following questions were posed:

- Explain in what way the abstraction of science present reading challenges to students.
- How did you use your understanding of abstraction to help your students read in your science teaching?
- Describe how students responded to your lessons that addressed abstraction in science discourse.

After we shared responses from the abstraction lessons, the facilitator reviewed the features of technicality and abstraction.

Discussion closed with the following questions.

- Explain what challenges technicality and abstraction pose to science reading.
- What do you feel are the challenges to integrating this information into your science teaching?

Module 6

- Date. January 2009
- Title. The density of science language and coping strategies.
- Objective. Teachers will understand how science reading is dense by examining sample texts and participating in model classroom lesson.

This session opened with a brief review of the challenges science reading can pose to students.

Expert review

In this session, participants were introduced in greater detail to the concept of density in science language. A power point presentation reviewed key components of how science language is dense. In addition, participants revisited the section about density in science language from *Reading in Secondary Content Areas: A language based pedagogy* (Fang & Schleppegrell, 2009) [pages 27-31]. In this text, the authors discuss the issue of density and provide clear examples of how and why science language is dense

Practice based discussion

In the second portion of the session, participants discussed strategies for coping with density. Chapter 4 of Fang, Lamme, and Pringle (2009) provided examples of classroom strategies for addressing the issue of density. Strategies modeled included: noun deconstruction and expansion and sentence combining. The participants then applied what they learned about the density of science discourse to their own practice by reviewing their curriculum materials and searching for ways to integrate the information into their daily plans.

Closure

The following questions were posed:

- How do you think this information relates to your teaching of science?
- What are your concerns about using this with your students?

Assignment

Develop a lesson plan using one of the strategies discussed in class. Bring samples and response to our next session.

Module 7

- Date. February 2008
- Title. The genres of science language and coping strategies.
- Objective Teachers will understand the genres of science by examining sample texts and participating in model classroom lessons.

This session opened with a review of the lesson completed on density. The following questions were posed:

- Explain what challenges the density of science language presents to science reading.
- How can you use this understanding of density in your science teaching?
- Describe how students responded to your lessons that addressed density in science language.

Expert review

The first hour was dedicated to learning about the basic science genres (i.e. procedure, report/description, explanation, argument/exposition). The science teachers viewed a power pint presentation about genres and then read several samples of science writing that included examples of the various genres.

Practice based discussion

In the second hour, the genre-teaching cycle was presented to the science teachers. This teaching-cycle was described in Chapter 4 of Fang, Lamme, and Pringle. The genre teaching cycle involves preparation, modeling, joint construction, and independent construction. Participants considered how they might implement the approach to teaching science genres in their own classrooms and began to develop plans for introducing the concept of science genres to students.

Closure

The following questions were posed:

- How do you think this information relates to your teaching of science?
- What are your concerns about using this with your students?

Assignment

Develop a lesson plan using one of the strategies discussed in class. Bring samples and response to our next session.

Module 8

- Date March 2008
- Title: Review and Reflection
- Objective: Teaches will share their final thoughts about using the ideas in their classrooms.

The session opened with sharing experiences with implementing the genre lessons in the classrooms. The following questions were posed:

- Discuss how you integrated your understanding of science genres into your teaching.
- How did your students respond to your teaching?

Expert review

This session was reserved for follow-up and member-checking. The expert review segment of this session involved a summary of key points from the study of science language.

Participant based discussion

Participants were invited to share closing remarks about their participation in the study and how they would use these ideas in the future. To close, participants revisited their concept maps and made adjustments based on their participation in the workshops.

Summary

In this chapter, the professional development design used for this study was described in great detail. In addition, specific details of each module were presented. The first two modules included an overview of the relevance of reading to science, focusing specifically on the challenges presented to students by the features of science language. The next four modules each further developed one of the four reading challenges discussed in the first module – technicality, abstraction, density, and genre – and suggested strategies that teachers may use to help students cope with each of these challenges. Included in this model were two sessions for review, one at mid-term and one at the end. Chapters 5 and 6 will report the findings from this study.

Table 4-1. Professional Development Meeting Schedule

Date	Topic	Time (Hours)
SEP 08	Preprofessional Development	2
SEP 08	The Unique Language Demands of Science Reading	2
OCT 08	The Technicality of Science Language and Coping Strategies	2
NOV 08	The Abstractness of Science Language and Coping Strategies	2
DEC 08	Midterm Review	1
JAN 09	The Density of Science Language and Coping Strategies	2
FEB 09	Genres in Science Language and Coping Strategies	2
MAR 09	Reflection and Review	1

Table 4-2. Vocabulary Thinkchart

Hydrogen gas (H) is diatomic at room temperature.	
Question	Answer
What is the target word?	Diatomic
Do you recognize any part of the word, such as prefix, suffix, or root (or base word)? What does each part mean?	di- two atom- smallest unit of an element ic- relating to
What does the word remind you of? Can you give a semantically-related word, an orthographically- similar word, or a real life scenario triggered by the word?	Diameter, diabolic, diatribe, atoms, atomic numbers, economic
How is the word defined in the text? Can you paraphrase the definition?	Hydrogen gas, H , is *diatomic* at room temperature." Diatomic means two atoms are in the element.
Can you come up with a sentence in which the target word is used in the scientific sense?	The atmosphere of the Earth is composed of mostly diatomic molecules.
This word is part of which larger science concept? What are some other words related to this larger concept?	Chemistry, physics Atom, Element, molecule, compounds,

CHAPTER 5
SCIENCE TEACHERS' PRIOR CONCEPTIONS ABOUT SCIENCE READING

Qualitative research methods are especially useful in uncovering the meaning that people assign to events (Creswell, 2007). In this study particularly, the use of grounded theory allowed the researcher to develop an in-depth understanding of the experience of this group of secondary science teachers as they examined the challenges presented to both teaching and learning by the complex nature of science language.

It is well established that secondary content teachers are conflicted about the usefulness of integrating reading strategies into their teaching repertoire. While most secondary teachers acknowledge that reading is important, evidence of consistent integration of reading strategies into daily teaching practice is scarce. Questions remain about how and if these teachers actually implement the reading strategies they learn about in workshops, textbooks, and college classes.

The first research question in this study, "What do science teachers know about teaching reading in science?" attempts to capture the prior knowledge, beliefs, and experiences of the science teachers involved in this study. In order to provide effective professional development, it is relevant to ask what experiences, beliefs, and understanding this group of teachers had about reading prior to the delivery of the series of professional development sessions.

The purpose of this chapter is to report findings about the teachers' prior knowledge, beliefs, and experiences with reading in science. This information was captured from four sources:

- the personal statements that teachers completed during the first session
- the group discussion that followed the completion of the statements

- informal follow up conversations and emails between the participants and the researcher

This chapter contains five sections. Section one describes how the teachers explain the role of reading text in science learning. Section two details the teachers' interpretation of what it means to teach reading in science. The third section addresses the teachers' beliefs about students' reading in science. The final section describes the instructional practices the science teachers currently use in their classrooms to address reading and the questions teachers pose about reading in science in the secondary setting.

In order to reference the data from this study, I developed a system to indicate if the data was from a professional development module (PD), a mid-term interview, (MT), a final interview, (FI), or an email communication (EC). I also included a letter reference to indicate who made the statement (e.g, JB, MC, PB). Finally, the professional development references include the date of the module and the numbers for the other references indicate page numbers from the transcripts

Reading in Science

Data showed that the science teachers in this study believed that reading was important in learning science. "Reading is the most important way to learn about science," (PD1- 09/2) Casey stated in our opening discussion. Patsy further explained, "Future consumers must be able to read and protect themselves and monitor their own medical progress" (PS-PB-2). Mona added that, "In order to know and learn what others have done, we must read their reports" (PS-BM-2). The science teachers acknowledged that science is a field in which reading plays an important role because new information is always surfacing about particular topics. For example, Billie addressed how in an older scientific text, Pluto would be identified as a planet, but now scientists classify Pluto as a dwarf planet (PD2-09/16-23). Lisa further distinguished how she believed that reading played a role in remaining up to date on current trends in science.

> Things like history and English are static. You know, a verb is a verb is a verb. A noun is a noun. George Washington will never be the third or fourth president. He's always the first. Whereas, in our field, marine biology, update, update, update. This thing is shifting over here. We're going to move this group over here. We're going to have - forget three phylums. We're now going to have six.
> We're going to rearrange these groups over here. I'll forget that classification. We're going to basket upset this. Chemistry, we're adding new chemicals all the time (PD1-09/2-11).

The science teachers repeatedly stated their belief that reading plays a major role in learning science and that it enables individuals to keep current on new ideas in science.

Another theme indicated in the data was that science teachers believed reading was important to their own personal science learning. Science teachers explained how they relied on reading to support their learning of scientific information in both personal and professional endeavors. For example, during a professional development session Bette described a specific course she took in college that influenced her personal reading of scientific information.

> One of my courses in college was just about medical terminology and science terms. We just learned prefixes, suffixes, and root word meanings, and it totally changed my perception of how I read scientific material. Like everything from medical journals to just the textbooks themselves and lab manuals. That type of stuff. As far as reading, that played a huge role because you had to read to learn the material." (PD1-09/2-2)

Casey added that reading also played an important role in how she made sense out of the concepts that were covered in her college coursework. She explained that she often did not understand lectures in her science classes. Only through reading her textbook was she able to make sense of the material. Casey explained how she would read and reread and look at diagrams until she could figure out the information (PS-MC-1).

Data showed that the science teachers also used reading to find information to supplement their teaching and improve their knowledge in science. For example, Lisa commented that she reads science information to gather data on topics she is covering in class; when she wants to know something about a science topic like the great white shark, she finds an article about it (PS-VL-2). Billie concurred stating, “If a student asks a question I do not know the answer to, I will do research on that topic so I can share it with my class” (PS-JTB-2). In order to understand particular science concepts or to find new information about a topic, the science teachers often gained information by reading scientific texts like research articles and books.

When asked what made science reading distinctive from other types of reading, data from the personal statements showed that five of seven teachers listed technical vocabulary as the top reason that science reading was so different from other types of required school reading. Casey stated, “The extensive and unfamiliar vocabulary in science texts can make reading science cumbersome” (PS-MC-4). Brad added that in order to learn science a person must know Latin roots and prefixes. He explained further during a professional development meeting, “If you enjoy science you must develop an understanding of scientific language. Most people do not enjoy Shakespeare, but once you learn the language, it is quite enjoyable” (PD1-09/2-9). Bette agreed sharing:

> If you're an English type of person, you're going to pick up a medical book and go ‘Oh my God!’ But once you know the terminology, you can read anything in science and feel comfortable. It's just the fact that you have to

> learn the terminology; the only way you learn it is by reading tons of material” (PD1-09/2-3)

Through show of hands during our discussion about how science reading was different from other types of reading, all seven teachers agreed that technical vocabulary was a major part of learning science. Lisa compared science vocabulary to learning a new language. She reiterated the consensus that science was science because it used words that were specific to science. She stated:

> And like Spanish or French, when you hit science, it's a new vocabulary. And the children who are lazy, don’t want it, can't make me, why do I have to deal with this? And my reply to that is everything in the ocean cannot be named Bob. If we're at the beach and I scream, "Look out. There's a Bob." Are you going to laugh or are you going to run out of the water? So we have to give things scientific names because if I’m in Japan and I scream, "Look out. There's a Bob." They don't know what's going on. But if I yell, "carcharodon carcharias," at least the marine biologists will be out of the water 'cause that's a great white shark (PD1-09/2-10).

Another theme that surfaced in the data when the science teachers discussed reading in science was the sharp contrast between science reading and novel reading. The science teachers acknowledged several ways that science reading was different from novel reading such as that it is informative, topic driven, and contains a lot of vocabulary. For instance, Mona commented that most students are comfortable with stories but have difficulty making connections to science texts which have more information (PS-BM- 3). Lisa added, “Science has no plot. Being written by scientists who tend to be factual and dry- science texts often lack humor or that human connection found in novels” (PD2-09/16). The science teachers expressed an awareness that science texts are different from typical texts students read for pleasure or in their English classrooms.

Data revealed that science teachers believed that reading science text played an important role in learning about science. Science teachers used reading for their own personal endeavors in learning science and used reading to further their own understanding of concepts to present to their students. When describing science text, the science teachers believed that it was distinctive from other types of text due to its high use of technical words that are specific to science. In addition, the science teachers indicated that science text was vastly different from the typical types of texts that students read for pleasure or in school.

The Role of the Teacher

Data about how teachers perceived the role of the science teacher in teaching reading can be separated into two themes. The first theme was that science teachers showed a willingness to accept the responsibility of teaching reading to their students. The second theme was that despite the science teachers' participation in many workshops and college courses, they did not feel adequately prepared to teach reading in science.

Because the science teachers believed reading was important in science, they were willing to teach their students to become better readers of scientific information. First of all, their participation in this study was evidence of their willingness to learn about teaching reading in science. During a professional development meeting, the science teachers elaborated about why they wanted to help their students improve in science reading. Bette connected her own experiences in learning about science to why she thought it was important for her students to know how to read science.

> As a biology teacher my whole thing for the year – I tell my kids, 'I want to try to break it down for you. I'm demystifying science for you. I want you to understand it so you get it. Because, I'm like, I was there. I wasn't a

> science reader. I went into science because I wanted to be a missionary doctor in the middle of nowhere Latin America and you know that was my heart. And here I am teaching science (PD1-09/2).

Patsy also thought it worthwhile to teach reading in science. In her mid-term interview, she expressed her desire to know more information about reading in science. Patsy explained that she decided to be a part of the study because she wanted to improve her own knowledge.

> You hear some teachers say, ‘I've always done it this way, I'm always going to do it this way and you're not gonna make me teach reading because I am a science teacher.’ You have to kind of think, ‘Okay that’s your choice.’ But, that’s not the choice I'm going to make. And initially to sign up for something like this, the opportunity was presented but not everybody was for it. I don’t have time for that but I thought, ‘No, I've done enough with a couple other reading books; I'd like to add another one, another piece in my learning ability so I can help my students’ (PB-MT-10).

Although the science teachers, showed a willingness to teach reading in science, data revealed the science teachers were uncertain about what it meant for the science teacher to teach reading. When asked about the role of science teachers in teaching reading, Patsy stated, “I think it's been the philosophy at our school for several years now that it is every teacher's responsibility. And I see it as reading comprehension, which is easier for me to think that I am capable of teaching than, you know, any sort of phonics or anything like that” (PD2-09/16-17). Lisa responded to Patsy:

> It's kind of an unfair situation to make a blanket statement like that [every teacher a teacher of reading]. It's a grandiose and idealistic statement. It's like saying, ‘We want everybody in this school to go out and run the Boston Marathon and win.’ But we don't care if you've been sitting on the couch for the last 25 years or if you go out and run everyday, you should all be out there running the marathon. I really have ambivalent feelings because my mother was an English teacher and I think, ‘Yes,’ and then my science teacher says, ‘No, I wasn't trained for this. I was trained to be a science teacher.’ (PD2-09/16-17)

Lisa felt inadequately trained to teach reading to her secondary students. During a professional development meeting, she explained:

> I realize that as a reading teacher I am woefully inadequate. But then, I have received very little training to be a reading specialist, let alone an intensive science reading specialist. My training involves teaching them to understand marine biology in whatever fashion I can devise, by breaking it down into manageable bites of data, both visually and orally. (PD2-09/16-18)

Casey further confirmed Lisa's hesitancy in being prepared to teach reading in her secondary science classroom. Despite her belief that reading was important and a valuable part of her own science learning, she was unsure of her ability to effectively address it in her classroom. She indicated in her personal statement that she was taking this course because she had attended many workshops before that addressed reading in the content areas but she still did not feel prepared to do it well in her own classroom (PS-MC-6).

It is important to note that the science teachers explained how the administration of the school expected that reading was a part of all of the content areas. With the emphasis on the Florida Comprehensive Assessment Test (FCAT), science teachers at this school were provided with FCAT sample test books to use for reading practice in the classrooms. In addition, a reading specialist provided mini-workshops and daily instructional support to the teachers. Another source of support offered to teachers is semester learning community classes. Three of the teachers in this study participated in learning community experiences where they read Chris Tovani's book *Do I Really Have to Teach Reading?* and Kylene Beer's book, *When Kids Can't Read What Teachers Can Do*. Casey commented that she felt the school level support for trying reading strategies in her classroom was outstanding, explaining that, "We have a school wide time for reading each day and are encouraged to include reading assignments within our content areas" (PD2-09/16- 22). Several teachers noted their belief that reading for pleasure was a valuable activity. Lisa said, "Teenagers will read until the cows come home anything as intense as Lord of the Rings or whatever, if there is an interest in it." (PD2-09/16-26). In this school, each teacher had a classroom library with a variety of books for kids. During the 5th period class, an extra 20 minutes is added to the class for personal reading. All seven teachers were supportive of this school wide initiative.

Despite the wealth of offerings at this school and the encouragement for incorporating reading at the secondary level, however, science teachers admitted that they still felt at a loss sometimes when applying the ideas to science. Billie commented, "There are some efforts to address reading in the content classes here, but the needs for reading in science are so different. I do not feel that this is addressed in the mini workshops that we have" (EC-JTB-1/18). The science teachers indicated that the topics discussed in faculty initiatives addressed motivation and generic reading strategies such as how to access background knowledge, fluency, or vocabulary. Casey shared that after attending a mini-workshop, she conducted a reading activity once a week for one month designed to promote fluency. "First I read a passage aloud and then the students read for one minute with a partner recording how far they got and we calculated how many words they were reading per minute." (EC-MC-03/6). While Casey was willing to participate in this activity, she did not feel it was something she would continue on a regular basis in her classroom.

The science teachers' experiences with learning about teaching reading were focused on generic reading strategies. Bette commented that she was able to mold some of the ideas into her science teaching like the logograph, but no reading training had dealt directly with science reading. Lisa said, “Other than school advisory giving us money for books and science FCAT practice books, we have seen nothing until this workshop that specifically addressed how to read science” (EC-VL-09/18). Brad elaborated on his previous experiences with professional development about reading in the content areas:

> They [workshop facilitators] basically gave us some reading and science literacy strategies and they pretty much just hand you the book and go through it for, like, an hour and then you’re on your own to use it, and they want you to implement the strategies in your class. And a lot of it was Venn diagrams and different reading strategies (FI-MB-5).

Data also showed that the science teachers faulted their college preparation for not being ready to teach reading in science. The science teachers said that the courses did not prepare them for how to address reading in the science classroom. Billie who was the newest teacher in the group indicated that the importance of reading in science was stressed in her courses but most of the strategies were about topics like finding the main idea or vocabulary. Lisa, who had over 30 years of teaching experience, said that reading was never addressed in her courses.

> Generic education courses really did not give us training on dealing with comprehension. It talked about sciences … motivating them [students] to enjoy sciences, motivating them to be curious about science, finding ways to reinterpret the data for the kids who are not getting it. (PD2-09/16-19)

Data concluded that the science teachers agreed that reading was important to learning science and that they were willing to accept the responsibility and explore ways to improve their teaching of reading in science. However, they did not feel adequately prepared to address reading in their classrooms.

The Role of the Student

The science teachers agreed that students struggled with reading science texts. Bette compared her own reading of college texts to how she believed an average reader encounters scientific texts:

> I remember having texts in college – particularly an organic chemistry text, where I felt like I was wadding through concrete backwards trying to comprehend what they were saying. And if you don't have a very abstract focus mind and you are a narrative reader that can be just murderous. And for a lot of these kids I think that is part of the problem. If you have an average reader and they get into reading the scientific text that it's like wading through mud and they get very, very emotionally and readingly exhausted and they stop and they don't wanna go any further (PD2-09/16-41)

Two themes emerged in the data to explain the teachers' perceptions of students and reading science. The first theme centered on what skills the science teachers believed that students were lacking in order to be successful readers in science. The second theme encompassed external factors that teachers believed influenced students' reading and understanding of scientific texts.

In the personal statements, every science teacher cited lack of vocabulary knowledge as a major deterrent to kids' not reading science. The science teachers expressed that students needed a strong understanding of vocabulary in order to access scientific texts and many students did not possess the knowledge of how to break words down in science to improve understanding. Casey explained that vocabulary knowledge was critical to understanding anatomy. During a professional development meeting, she explained that:

> Kids get turned off in science when they do not know the vocabulary. And there is so much new vocabulary it is challenging to learn it all. But, if you do not know it, it is impossible to develop an understanding of certain topics. Like, in anatomy, there is a lot of very technical vocabulary to remember. And it is important. (PD-2-09/16)

Brad also noted that vocabulary knowledge was important to learning about new topics in science. He stated, " . . . the vocabulary in science is usually new and does not always repeat from previous years so learning new vocabulary is always an issue in reading science at this level" (PD2-09/16). The science teachers agreed that vocabulary was their primary concern when considering issues around reading in science and that many students lacked the necessary vocabulary skills to be able to read science.

Another skill that the science teachers believed that students needed was to be able to extract main ideas and identify important information. The science teachers concurred that students often read quickly through assignments and could not identify the important information from the text after reading. For example, Mona said, "They [students] just read for a very superficial understanding, these are the signs of inflammation instead of really trying to discern, what does this mean?" (PD1-09/02). The teachers agreed that students generally struggled when asked to read to make connections between ideas or find themes. Patsy commented that, "You know, they don't have that comprehension to take it and spit it back out in anything other than rote memory in the sense of, I know that definition. I can tell you what it means. But now to use it where I need it, won't happen" (PD1-09-02). Billie added, "You know, they can spit back the information to you. Like, alright, I memorized that. But they have no idea how it's relevant to real world" (PD1-09/02).

Bette gave an example of her students struggle to find important information in science texts. She explained how she tried to use the reading strategy of a graphic organizer to help her students take notes on a section of the textbook she assigned for them to read. She anticipated that the organizer would help her students locate important information. However, she did not get the results she wanted.

> I thought, “Oh great, they're just going to flow through this” Yeah, right. I don't get it. They didn't know what important information was and how it was connected to the other information, although we had gone over it. (PD1-09/02-14)

The science teachers expressed that students’ overall comprehension of scientific texts needed improvement. The teachers noticed that students struggled with reading science texts and understanding scientific information. For example, Patsy stated, “Our students struggle in general with interpreting science concepts” (PD1-09-2). When probed further for what skills students needed to comprehend scientific texts, the teachers listed being able to evaluate diagrams, compare science themes, analyze trends in data, and interpret the science into their own words as all being important. Bette explained:

> I talked to my kids today. A mark of intelligence is that someone can take something they've seen, they've heard, they've read, interpret it, figure out what it means, put it in common language, be able to explain that to somebody else. Or break it down, give an example. And I talked about that today with my kids. So we looked at a quote. And I'm like, okay, what does this quote mean in your own words or give me an example. Something. I got a few responses but like the whole idea of reading for content, some of mine can't get the main idea from the fluff. And that's something I've tried since day one already with my kids. I'm like, let's read this paragraph. Once we do read alouds, stop, what was that about? Give me the main points. And some of them get it, but some of them; I can still see they are just like, I don't know. (PD-09-02)

Lisa said that as a secondary teacher she expects that her students are ready to read independently. She commented during an interview that:

> When we get them [students] at this age, there is an expectation of us, being secondary teachers that these children know how to read. They know how to read anything. They know how to read well. We have to teach a few vocabulary words and we're off and running. But this is not the case. (MT-VL-7)

Data revealed that teachers believed that technology negatively influenced students' reading performance in science. The science teachers blamed the surge in technology, claiming that the students are more interested in quick, immediate information rather than having to sit and read challenging material. Brad commented, "I mean we just need a complete power outage of the school where no electronic devices can go on to get them to read. Because everything is video and audio. They're either listening to iPod or text messaging on the phone, which they're reading, which has no significant value whatsoever. People don't sit down and read" (PD1-09/2-2). Lisa added,

> I think that sometimes the kids want to be over stimulated because that's what they're so used to. Their video games just have all this stuff going on. Unless you get out there and you have the magic show going on and three other things going. They're just like zoned out. So to sit and read a book for some of them is just over the top because if you don't have the radio on, the TV on, and your book open, it wouldn't work real well for some of them. (PD1-09/2-2)

Teachers felt they were competing with the technology that was such a big part of their students' lives. Casey said she struggled to convince her kids to read their textbook. She explained:

> We have kids today that are readers but they're getting more of it on the online, and the shorter, quicker things. And that's not going away. So how are we going to be able to utilize that or change what we have? I mean, 'cause I'd like to say, boy this is really a great anatomy book and you just really need to read this. But that's not how it works. (PD1-09/2-3)

Patsy described her students' participation in reading assignments as "uninvolved". She explained further:

> They read it because I said read it. Not for any other reason but Ms. B assigned to read these four pages. By golly, I will read them so I can say I've read them. And they don't sit there and say, okay, well this is my goal I have to read this . . . They really just pick it up and read it 'cause you said to

> read it and not - they're just reading the words but not- absorbing it. (PD1-09/2-5)

Lisa further confirmed that her students do not want to read the science textbook in a professional development meeting she commented, “They [students] get to high school and they don't want to read, in general. 'Cause you have those kids, during your reading time going, ‘This is really dumb.’ They don't want to read. They don't have that interest to read anything (PD1-09/2-6).

Data also showed that teachers cited interest as a problem in motivating students to read science texts. Brad explained that the reason kids do not read science is due to interest.

> It's a motivating factor. If I don't have a reason to read this, I am not reading it. 'Cause they're not interested in what's there. Most of them. Some of them are because you're on a cool topic when you get to physics or something. They don't care about density and volume right now. They learned that in sixth grade. They're not going to sit there and read about it again. (PD1-09/2-9)

Bette responded to Brad claiming that kids were interested in science topics but just did not want to read about it. She explained:

> I think a lot of these kids get in here and they have an interest in a lot of the topics. But, they don't want to deal with reading. The heavy duty, plowing through the techno-reading 'cause they find it dry or the fancy terminology. They want to break it down in familiar terms for them. And they want the reading to be equally simplistic. (PD1-09/2-10)

The science teachers discussed Bette’s point and agreed that they could build interest in a topic, but not necessarily in reading about that topic. The science teachers agreed that getting students to participate in reading about science was a challenge. Patsy indicated that her students readily told her they do not read their textbooks. When she asked her students about reading their science textbooks, she was shocked.

> I asked my students over the last years, how many actually open their textbooks and read. And I was appalled, maybe a quarter. Most of them say, I don't have to crack the book. I can listen to the teacher, take notes, and I'm good. And it's like; you are not reading your book now. Well, I don't need to. You give me the information in class. And I thought, well, then they've got a point. (PD1-09/2-9)

Data showed that the science teachers believed that the students did not have the necessary skills in order to read science effectively. Teachers identified the skills that students needed in order to read science well: (a) knowledge of vocabulary, (b) the ability to locate main ideas and important information, and (c) overall comprehension skills. Data further indicated the science teachers blamed the influences of technology and student interest on students' low performance in reading science.

Instructional Practices

Data indicated that teachers were using reading strategies in their science teaching. Reading strategies identified by teachers included graphic organizers, note taking, guided worksheets, and vocabulary strategies. The science teachers also used reading aloud as a strategy to read textbook excerpts.

The majority of the strategies the science teachers used dealt with vocabulary. For example, Casey, Patsy, and Billie all used logographs consistently in their classrooms. A logograph requires the student to choose a vocabulary word and provide a definition and an illustration. Patsy said she also assigned vocabulary words at the beginning of a chapter and asked students to define the words. Brad and Bette taught students how to break down vocabulary words into meaningful units. During a professional development meeting, Brad shared how he helped students to understand how to break down words in science:

> I said, guys you probably don't know what this word means, but I bet you can figure it out. I said, because you know the prefix bio. You know the

> root word, mass. Let's take it apart. And they figured it out. Really? It really means that? I'm like, yes. See, you can do this. (PD2-09/16)

The science teachers also discussed how they used textbooks in their classroom. They agreed that the textbooks were written at a higher reading level than most of their students are capable of reading. Mona stated, “I think a lot of our textbooks are too hard fro them to read to be honest” (PD1-09/2-24). Casey commented, “I am selective in the parts of the text that I expect them to read for comprehension since they are so hard” (MT-MC-7). Casey often rewrote reading passages from the textbook to make them more comprehensible for students.

Lisa also felt the textbook was too challenging for her students to read. She explained:

> I have them read but they struggle with doing this. But I try to have them read their textbook and then like construct from the reading, you know, like microscopic _____ _____. And I try to do various activities like this. And they really struggle with it. I think the text is written at too high a level. So they really struggle with it, and I end up helping them more than I intend to because my intent is to have them read it, and then build it so that I can see that they comprehend it. (PD1-09/2-23)

When asked about the amount of time the teachers asked kids to read in class, there was a momentary pause. The following script shows the teachers’ responses:

> **Bette:** Are you talking reading text or reading the overhead projector that's flipping through the screen?
>
> **Facilitator:** Reading a text.
>
> **Brad:** Reading my notes? (Laughter)
>
> **Casey:** Whole paragraphs, actual text-
>
> **Bette:** In the actual classroom?
>
> **Facilitator:** In your actual classroom.
>
> **Billie:** I'd say five to 10 minutes probably per class. 'Cause when we do read alouds, I'm trying to think about - I usually got, by the time I do all the

beginning stuff, after stuff and everything in between, maybe 20 minutes of actual lecture/let's read this material aloud and then we discuss it. Well, _____ together and discuss it or a couple of paragraphs and discuss. So they are actually reading. But I would say, maybe, five to 10 minutes.

Facilitator: So most of the independent reading is assigned versus doing it in class?

Bette: Yeah, I can honestly say I don't recall ever saying, everyone - well, I'll say take a moment to skim through this page right here. Now let's discuss. I've done that. But I've never taken time to say; alright we've got five-

Brad: Take 20 minutes and read.

Patsy: Take 20 minutes to read your textbook?

Brad: I'm saying, taking 20 minutes to read your textbooks - crawl off the walls and get crazy because they won't.

Patsy: Unless you have something there that has questions and they're looking for information.

Billie: Right.

Brad: A worksheet.

Casey: That's actually a good strategy.

Brad: It's being graded, of course. It's gotta be graded.

Bette: Is this for a grade?

Brad: Because, again, it's a motivating factor. If I don't have a reason to read this, I am not reading it. 'Cause they're not interested in what's there. Most of them. Some of them are because you're on a cool topic when you get to physics or something. They don't care about density and volume right now. They learned that in sixth grade. They're not going to sit there and read it. So having a worksheet might be a way to help them read but if I have them 20 minutes - my kids, up the walls. (PD1-09/2-23)

In this same conversation, all seven teachers said that the primary source of reading in their classrooms was the textbook and that was mostly assigned as reading for homework or when students completed a test. Five teachers used the FCAT workbooks as an alternative reading source. All teachers had a classroom library as required by the school, but the shelves were filled with a variety of books, not specific to science.

Overall, the science teachers believed that reading in science was important and all had tried various instructional strategies including vocabulary, note-taking, and general comprehension activities. However, the science teachers were still filled with questions and curiosity about how to improve their instruction in reading science. On their personal statements, teachers listed that they wanted ideas to help students to access difficult texts. The science teachers also were interested in more vocabulary strategies to help students with the technical reading in science. Every teacher listed wanting help in improving overall comprehension. Bette explained, “I would like some specific strategies to use to help my students see the big picture because that seems to be where they're weak. They can pick out all these details but they just don't get the big picture” (PD1-09/2-21). Casey stated:

> Most of us enjoy reading and have always enjoyed reading, whether the subject matters change, you've always been a reader. And today's kids are getting more of it on the online. . . so what are some strategies or ways we can make it more applicable to today's kids? (PD1-09/2-21)

Mona wanted to gain a better understanding of strategies she had learned in previous workshops. She wrote, “I would like some new reasons for reading aloud for comprehension rather than fluency” (PS-BM-6). Billie responded, “I need to understand how to make the difficult science text more accessible to the students. How can I help kids comprehend difficult material?” (PS-JTB-6). The science teachers wanted to know how to improve their instruction in order to help their students.

In summary, the science teachers were using generalized reading strategies in their classrooms like graphic organizers, note taking, and guided worksheets to address reading in science. The science teachers were also using vocabulary strategies like logographs and breaking down words into Latin roots. However, the science teachers had limited success with these strategies and were interested in more instructional practices that would assist them in teaching their students how to read science successfully.

Conclusion

This chapter captured the science teachers' prior conceptions about reading in science. Teachers' discussions were centered on their perception of the role of the teacher, the student, and the text in addressing issues of reading scientific texts in secondary settings. The final section of this chapter illuminated the science teachers' pending questions about teaching reading in science. The following chapter will report the results of what the teachers learned about the specialized language of science through their participation in a professional development effort.

CHAPTER 6
SCIENCE TEACHERS' NEW UNDERSTANDING ABOUT SCIENCE LANGUAGE

The findings reported in this chapter capture the teachers' perceptions, understandings, and knowledge as they studied the language demands of secondary science texts and put into practice what they learned about new ways of teaching reading in science. Chapter 5 described the science teacher's prior conceptions about science and reading. This chapter will describe what they learned about science language and the factors that influenced their new understandings about science language.

The results presented in this chapter were generated from the final two research questions:

- What understanding about the distinctive language features of science do the science teachers construct through professional development?
- How do they integrate what they have learned about these specialized language features of science into their teaching practices?

It is important to look at these questions together because the teachers' understanding was evidenced in and influenced by their attempts to put the ideas into practice. The process was iterative because the ideas were presented in the professional development sessions; the teachers put the ideas into practice, and then returned to the professional development sessions to discuss their understanding.

The following data sources were used to gather information: (a) transcripts from the professional development modules, (b) interviews with the participants, (c) classroom observations of the participants, (d) participants' written email communications and (e) informal conversations between the participants and the researcher.

This chapter is organized around three findings: (a) The teachers were excited about learning disciplinary reading practices, (b) Teachers recognized the comprehension challenges these specialized features present to students and (c), Teachers developed emergent awareness of the specialized features of scientific language (e.g., technicality, abstraction, density) and the various genres of science writing.

Teachers' Excitement for Learning Disciplinary Reading Practices

The science teachers found value in learning about reading strategies that were specific to science. Chapter 5 established that prior to this experience, the science teachers' perspectives on language in science were primarily focused on the difficulty of the vocabulary. The science teachers were unfamiliar with thinking about issues of abstraction, density, and genre in their consideration of how to teach reading in science. And further, they had not previously considered how the features of science language contributed to the development of ideas and theories in science. From their experience in this professional development effort, however, evidence showed that teachers were excited about learning about disciplinary reading practices and were beginning to think differently about language in science.

For example, in her final interview, Patsy addressed that looking at how language functioned in science was a new perspective to her. Although she knew that science language was filled with technical words, she had not considered how the technicality contributed to the complexity of science language and further, had never learned about the concepts of abstraction, density, or genres in science language. She explained:

> Initially, I already knew that it was highly technical. The part I was not aware about was to unlock a deeper level of understanding with the students to focus on how the language was used in science text. But I

> definitely see the approach to the science reading is so important, that it's the language. Why did the author choose to use this genre? Why did the author choose to use these words? What is he actually trying to say? (FI-PB-1)

> But I think what I've learned the most from our seminar here is looking at the actual language itself; how it is used. How silly but to get them to think the language. That approach has never been brought to attention in any workshop that I've ever been to. (MT-PB-5)

Lisa also confirmed that that looking at the language of science and it features was new to her. She addressed that typically when looking at reading in science, the focus had been on issues like cause and effect or main idea versus the language issues we were discussing in the professional development.

> I think in looking at teaching science from a language point of view is utterly, utterly brilliant because we go in there and we teach it like it's science, cause and effect, main idea, yet- so much of science is learning the lingo so we have to be like a foreign language – I would love to see science teachers trained to view what they teach as a foreign language because it is. (MT-VL-3)

This idea of looking at science through a language lens was new to the science teachers. Patsy contrasted her prior knowledge about science teaching with her new awareness about the language features.

> We always are taught hands on, hands on - they've drummed it into us. And as scientists and science studiers of the process, we jump right on that. But there is more involved and I never stopped to think about it's not just the labs, it's not just the hands on, its' the language approach too. (FI-PB-12)

> Bette's ideas further supported this finding that the science teachers were reconsidering their thinking about reading in science. She explained how her own views of reading science had shifted and she was now thinking about how certain aspects of science language contributed to its level of difficulty to comprehend.

> The way I'd say science language is different is that, first of all, it's very technical. We know that with the extensive vocabulary that is found in science. It's like a whole other language in itself. It's just very complex. The sentences are usually much longer. They use complex nouns, as you've explained before to us, now I realize that. Therefore, I think people

> just find it more difficult because it's not narrative. It's expository writing, a lot of explanation, a lot of details that you don't find in normal, everyday language. (FI-JB-1)

The science teachers recognized that looking at science text through a language lens was offering them new insight into how to teach reading in science. Teachers often expressed that now felt they had a "new set of tools" to teach science. For example, Lisa stated in an interview:

> And this gave us a whole box full of tools that are eminently useable. We know how to do them. You took us under the hood of the car and showed us this one will loosen this nut and bolt – it's like oh, light goes on. I feel much more - and I really love this word – empowered. I really feel more empowered to help the students deal with all these aspects. (FI-VL-4)

Bette also was excited about the new strategies she had learned in the professional development modules to address reading science in her classroom. She stated:

> And as a teacher you are aware that they don't all love science. And some of them, they'll say, "Ms. Bette, it's nothing personal. I just don't like science." And so that, to me, it is a goal that I try to change that for them. And I think giving them the understanding, the tools, the – some of the strategies that I've learned will help with that. (FI-PB-2)

The science teachers embraced learning about the role of language in reading science. Thinking about language was new to the teachers and they were excited to learn how language functioned to create meaning in science. They felt they had a new "set of tools" to teach their students how to successfully read scientific texts.

New Understanding about the Challenges of Science Reading

The science teachers also grew in their understanding about how the complexity of science language contributed to the challenges their students might have in reading scientific texts. Evidence from interviews and meetings confirmed that the science teachers' views of why students struggled to read science changed. Chapter 5 established that the science teachers shared a common belief that reading science was difficult for students. Prior to this study, the science teachers addressed issues of student behavior, technology, student interest, and poor preparation from early grades as reasons that students would not or could not read science well. However, after participation in this professional development study, the science teachers' understanding changed about why science is difficult for students to read.

> For example, in his final interview, Brad shared that he now saw how understanding the language of science could impact the way students read and learn from scientific texts. "I now think it's very important that they understand the language, and if they understand the language they can understand the material" (FI-MB-4).

> Casey explained that her new understanding about science language impacted how she viewed her own responsibilities to teaching reading in science. For Casey, her familiarity with reading science had inhibited her thoughts about why students might struggle with reading science. She admitted she thought students were lazy or just not interested. In the following excerpt from her final interview, Casey described how she has adjusted her thinking about reading in science.

> I had become so accustomed to reading science material that I didn't really realize that the students would have difficulty with it and why. Now, I'm more aware. In the past, I just became frustrated that they don't read their books, or I would be frustrated with the writers of the books because like, why can't they make a book that the students can read and understand? Whereas, now, I understand that what we have going on here is the fact that the students are more familiar with narrative and other types of writing. They're going to have to eventually be able to read science text, so we're in that kind of transition where we have to get them to do something that they don't feel comfortable with. I have this awareness now that, okay, it's not just that the students don't want to read, it's not that they can't write a text that the students can read. Now, I do see my role more clearly as having to give them some strategies that can help them to be able to get more comfortable with science reading since they're going to need to be able to do it in the future. (FI-MC-7-8)

The science teachers' now realized that unfamiliarity with the features of science language could contribute to why their students did not read scientific texts well. One of the issues the science teachers addressed when talking about student learning was how the differences between science language and everyday language could contribute to students' difficulties in reading science. Bette explained how she now realized that students' struggles with reading could be due largely to the complex nature of the language of science.

> When we first started talking about language I don't think I recognized why they [students] had difficulty reading science. I don't know if that makes sense? Like I knew they struggled with it, I knew that it was hard and I knew it wasn't something they were used to reading– but I never broke it down to the level that we talked about in the sense like the reason they don't understand it is because they take common words they're familiar with and make them so much more complicated and use them in new ways. So it was kind of like a learning process for me and then "ooh, pass that along" 'cause now I kind of understand, "Oh, well that's why it's hard." (FI-JB-9)

Brad also showed growth in his understanding that science language was unfamiliar to students because it differed from how students talk in their daily interactions. In his explanation of why student's struggle with reading science he articulated, "It's [science language] not the everyday language that we speak in today's society" (MI-MB-6).

Billie further confirmed that she now understood that the complexity of science language provided challenges to her students.

> Science language is more complex. The kids enjoy reading stories but science is not written in story form, it's not written in our everyday dialogue. They [scientists] take vocabulary that the kids know and use it in a way that students say, "I don't know what that word means" or they assume they don't because the textbook authors tweaked it a little bit or used it in a new way. (MT-JTB-8)

The science teachers now recognized that not only did science language differ from the way students talked, but it differed from a majority of the texts that students typically read in school. The science teachers examined how the components of narrative text were more familiar to students than the expository texts of science. When comparing the features of for example, a Harry Potter text, the science teachers listed story structure, main characters, and a theme that related to students' lives as features of narrative writing that made it more comfortable for many of their students (PD2-9/14-22).

In another example, Bette explained her understanding of why science reading is more challenging to students during her mid-term interview: "I think people just find it more difficult because it's not simple, it's not narrative. It's expository writing, a lot of explanation, a lot of details that you don't find in normal, typical texts that people read" (MI-JB-9). When Casey explained why students struggled with science reading, she also acknowledged how the students' familiarity with narrative structure impacted their transition into reading science. She said, "Students are predominantly exposed to narrative genres prior to reading science. When they get to science it is a whole new way of reading that they are not used to so they tend to not want to do it." Billie shared, "The kids struggle because of the differences between what they're used to reading in the younger grades, per se, and what they have to read now [in science]- it is so much more complicated and dense" (MT-JTB-1).

The science teachers showed an increased understanding of how the unfamiliarity of science language could contribute to the challenges students have in reading scientific texts. They addressed how the science language differed from the everyday language of students and how students were more familiar with the features of narrative reading versus science reading. The science teachers' increased awareness of the complexity of science language changed their perception of why students might be disinterested or challenged by science texts.

Understanding about the Features of Science Language

When asked about reading in science, the science teachers' responses during meetings and interviews showed evidence that they were developing their understanding about the complexity of science language. The teachers were able to identify and discuss the features of science language presented in the professional development modules. For example, during an interview, Casey summarized her new understanding of science language as follows:

> Science language is different because of the technicality, which basically has to do with the words that are either unique to science or they may be words that the students are familiar with in their everyday life, but they have a different meaning in science. Another difference is density, which is the amount of information that the students are given in one sentence. Then another one is abstractness, which has to do with a word referring to a whole process or a concept. (FI-MC-4)

Lisa further explained her new understanding of science language during a final interview.

> Technical, abstract, dense, a whole different vocabulary, terminology, meanings, words in English that have one definition that students may be used to have completely different definition in the science terminology. When students have got to jump into reading science they're reading a foreign language. You have to be a foreign language teacher. You have to get them [students] past the fact that it is not only a foreign language but that the books are written in expository not narrative. The language itself is technical. It's dense. It's abstract. So there's no point of reference for them. (FI-VL-1)

Although the teachers' sense of the complexity of science language was emerging, there was variance in their understanding within each feature. The next section will detail the science teachers' progress in learning about the features of science language. This section will address more specifically how the teachers' understanding of each feature of science language - technicality, abstractness, density, and genres - developed through the course of the professional development program.

The next section will cover how the science teachers used their new knowledge to integrate strategies into their teaching practice.

Technicality

Science language is technical because it uses two types of words that are specialized to science. The first set is words that are created specifically to name key concepts in science (e.g., lithosphere, plate tectonics). Technical words such as osmosis that describe key ideas or deciduous that name a type of tree are found only in science related reading and must be understood in order to comprehend important science concepts. The second set of words is common words that are used in specialized ways in science (e.g., medium, library). Technical words like fault can mean a flaw in everyday language but in earth science it means a crack in the earth's surface.

The science teachers rated their understanding of technicality as an average of 4.8 on a scale from 1-5 with 1 meaning the lowest level of understanding. The science teachers were familiar with the technical nature of science language and moved easily into understanding how technical words contributed to the complexity of science language.

Chapter 5 established that the science teachers identified the vocabulary in science texts as the primary reason that science reading was challenging to comprehend. The teachers were already using a variety of strategies in their classrooms that addressed vocabulary. For example, Patsy stated, "Morphemic analysis. I had already done the in the past. So that I was comfortable with it. It was like, 'oh good, I'm doing something right here'" (MT-PB-5). Because they were familiar with having to teach vocabulary to their students, the science teachers expressed feeling comfortable with learning about technicality in science language. Casey explained why she rated her understanding high on technicality:

> I had the most background knowledge there [technicality] to begin with and then, of course, built upon that. I feel very comfortable with the analyzing the word parts.That's something that I had actually done before. Not in such a systematic way as we learned how to do, but I feel very comfortable with that. (FI-MC-1)

Bette also indicated she rated her understanding high because the information she learned about technicality was closely related to ideas she had tried in her classroom.

> Technicality I was real comfortable with. It's – I gave it a five. I do a lot of that stuff already. I break the words down. It's just the nature of teaching, in a sense. You – I do, I don't know if all the other teachers do it, but when I – with science, I always teach them you know the word. Like, you know this word and this word, now put it all together, and it means what those words mean separately, but, you know, joined or whatever. And some of that – so that came easy to me, cause it was something I was already doing and I tweaked it a little or adjusted a little, but that – and understanding all of that was easy, cause I already did some of it and pieces of it and just kind of expanded a little to add some of the things that you had talked about. (FI-JB-1)

After participation in the professional development modules, evidence showed that the science teachers were able to explain how technicality contributed to making reading science challenging. One of the issues with technicality addressed in the professional development modules was how the technical words in science can be separated into two tiers- those that are specialized to science and those words that are common but used differently in science. The first category, scientific words, involves all words that are specifically used in science such as biomass and vestigial organs. In their final interviews, all the science teachers were able to explain that science language was technical because there are so many words that are particular to science. They noted extensively that many words in science are vastly different from the words students use in their daily lives. Casey explained, "The vocabulary is unique to science in some respect. A lot of these terms are not terms that students would have been exposed to just in their daily lives necessarily" (MT-MC-10).

In a mid-term interview, Brad explained his understanding of how science language is technical, "Science language, a lot of the words are based in Latin, all of the roots and suffixes. So it's pretty technical and it's not the everyday language that we speak" (FI-MB-1). Patsy explained her understanding of technicality, "Some of the aspects of technicality are there are a lot of vocabulary words for different things; for different processes; for different namings; for different describing words. Like a deciduous tree. How is that different from an evergreen tree?" (FI-PB-1). Patsy continued explaining that technical words like evergreen and deciduous are uncommon in every day life and so as a teacher, she realized she had to directly teach students the meanings of these types of science words. Bette further stated that she told her students, "Science words are more technical, which means they're not the common words. They're just more complex" (PD3-10/22-25). The science teachers' explanations demonstrated their understanding of how science language uses words that are specialized for science.

Although the science teachers were familiar with the way that science language used words that were specialized for science, the concept of common words being used in new ways in science was new to the science teachers. Prior to this professional development experience, the science teachers had not considered how common words used differently in science could pose problems to students' comprehension of scientific texts. The science teachers expressed surprise in thinking about technicality from this perspective. For example, Brad stated, "I never thought about the other – the other layer, which is that familiar words are used in a different context" (PD2- 9/16-25). The idea of common words taking on new meaning in science was also new to Bette. She explained how it had not occurred to her that students might be confused by this type of technical word. She stated:

> What I didn't know was the whole aspect of using familiar words in a different context. Like sponge. I knew a sponge, yes, it's a cleaning tool, but it is also an animal. And even when you show them, 'Here's a sponge.' They go, 'Oh, that's nice.'Students don't know what it is. They never thought it could be an animal. 'That can't be an animal. It doesn't move. It's not like a dog or a cat.' So that kind of aspect of technicality, I thought, was different. You know, I didn't even consider fault because I taught earth space. I know what a fault is. But you ask a student to define fault for you, and they'll say, 'Well, it's, you know, a different context. It's something that's wrong.' And they don't even think – they don't even remotely think go to crack in the earth because of an earthquake. (FI-PB-5)

During the professional development module where technicality in science language was covered, teachers were asked to look through their textbooks for examples of technicality with common words. Patsy and Bette found the following example from a biology book.

> Sperm are mobile cells that can propel themselves by lashing movements of their tails.

> Bette explained why she thought this was a good example.

> Tails especially – tails can get them off to start thinking about animals, like they're thinking about a different kind of tail or a horse. And because tail is a homonym and you know maybe they read the word and they think of *Tale of Two Cities*. You know that could be an inference just in terms of the word could bring up different meanings and connotations with them. (PD2-9/16-51)

The science teachers were beginning to see how the issue of technicality involved not only technical words that were specific to science like photosynthesis but also common words that were used in specialized ways in science. Brad stated during a professional development session, "I hadn't really thought that, but the presence of those kinds of words that can have double meanings. In your example of like you know 'What's the matter,' talking about matter, can make the language more challenging for students" (PD2-9/16-52)

Although the idea of common words taking on specialized meaning in science was new to this group of science teachers, the science teachers demonstrated growth in understanding when asked to explain how science language was technical. For example, Patsy explained her understanding of technicality during her final interview:

> Technicality is words that are unique to science. But I never thought about the other – the other layer, which is that familiar words being used in a different context. With technicality I knew how technical the terms can be. It's a whole new vocabulary that they're having to learn in science. So that level, I was okay with. So to rate the understanding level, I would say my understanding there was 5. What I didn't know, and the part I would say maybe a 4.5 was the whole aspect of using familiar words in a different context. (FI-PB-5-6)

Bette also addressed both levels of technicality in her midterm interview. She was able to explain how the technicality of science language involved specialized words and common words.

> Concerning technical words, yes, those – the everyday words that we use in science, and then we have the technical terms, the science terms that are only found, pretty much, in science alone like nucleus. Whereas, some other words that are everyday words but used at – using different meanings in both everyday language, and then science language would be like library – like the library of DNA versus the library we go to pick up books.

Another theme in the data was that teachers were able to explain how technicality contributed to problems in students' ability to read science. In her mid-term interview, Mona explained her understanding of how technicality impacts students' comprehension of science texts.

> The student is going to be familiar with the word but it has a different context and a different meaning. So that can be much more confusing for them because they're reading the word and it's not making sense in how it's

> used. We use words in ways that ordinary people don't use them so the vocabulary is different; and it's one of the things that I try to emphasize with the kids (FI-BM-1)

Casey also connected her understanding of technicality to student learning. She indicated that her new understanding of technicality changed how she thought about why her students may have difficulties reading science information.

> The information we read and discussed about technicality has increased my awareness of how and why students may struggle with the vocabulary and writing style of science resources. Having worked and studied in the science profession for years, I have become so familiar with these aspects of science that I had lost my perspective of how foreign it is to our students. I now realize that I need to refocus with less emphasis being placed on "covering" the curriculum and more emphasis being placed on comprehension of important concepts and helping my students to read science so that they will become life long learners of science. (EC-MC-10/10)

The science teachers demonstrated a change in their understanding of how science language was technical. However, when discussing science language, the teachers did not address why science language needs to be technical in order to communicate scientific information. Data revealed that teachers were mostly concerned with how it was technical and how the technicality was a factor in students' difficulty in reading science.

Abstraction

Science language is abstract because the nouns of science are words that represent abstract concepts like significance and discovery. An abstract noun incorporates the processes or qualities of the words from which they are derived. In science language, the abstract nouns function to help the scientist repackage information to build theories and arguments.

On a scale from 1-5 with 1 being the lowest level of understanding, the science teachers had an average self reported rating of 3.8 for how well they understood the concept of abstraction. Abstraction in science language was unfamiliar to the science teachers and proved to be a challenge for the teachers to grasp the related ideas and implement the strategies into their teaching practice.

Two themes emerged in the data to explain what influenced science teachers' understanding of abstraction in science language: (a) misconceptions and (b) attention to process. First, teachers had to overcome previous notions of how the word abstraction fit into their knowledge of teaching science. Second, the teachers focused their learning on understanding the process of making words abstract instead of how that process influenced the development of scientific ideas and the complexity of science language.

The first category, misconceptions, explains how the science teachers had to overcome their own preconceived notions about abstraction in order to better understand abstraction as it pertains to science language. When first presented with the idea of abstraction in science language during the professional development sessions, the teachers were confused about the difference between an abstract concept like Bernoulli's Principle and an abstraction as it is used in science language. They associated their new understanding of abstraction in science language with their previous concept of an abstract idea in science.

For example, Mona did not understand how abstraction applied to teaching physical science. Her misconception that the word meant abstract ideas inhibited her ability to understand why science language was abstract.

> The abstractness, I can skip in my class because everything we say you can put a hand on or draw or take a picture of. They're all pretty physical. I mean even the periodic table. It's in every room in our science department. The periodic table is a thing. It's not just an idea. It's a thing. It's right there. The abstractness isn't that much of a problem in my classes because I'm with the freshman in physical science (MT-BM-4).

In another case, Casey talked about understanding abstraction in the midterm interview. She explained how she associated abstraction with scientific concepts that could not be easily seen or touched like cells or DNA. She had to change her perception of the word abstraction to include thinking about how science language could be abstract.

> I started out with a misconception that abstractness had to do with the fact that many of the concepts in science are not something that the student can see or touch. That was my idea of abstractness. I had thought about science as dealing with abstraction but just more in that a lot of it is not concrete, visible, they can touch it because we might be talking about something microscopic, you know, something that we only have theories about how it works. We don’t even really know because nobody can see it, touch it, feel it kind of thing. So that was my idea of abstraction in science prior to this. I had just never thought that a word could be abstract because it has so much information in it. (MT-MC-11)

Patsy expressed a similar challenge in learning about abstraction. She also had to begin thinking about abstraction in terms of science language, not just only terms of what can be seen or unseen. She said, “I thought, ‘Well, it’s abstract because it’s not concrete.’ That I had, of course. But that was not what it is. It is the language. So that was my misunderstanding of the whole abstraction” (FI-PB-5).

The three teachers’ description of their understanding is evidence that the science teachers struggled to make sense of abstraction in science language. The teachers defined abstraction in terms of concepts and ideas in science that were intangible. Good examples of this are *cells* and *mitosis*. Prior to their experience in the professional development modules, the science teachers had not thought about the possibility of science language being abstract.

The next category, *attention to process*, captures how the science teachers focused their learning on knowing how to change words from verbs or adjectives into abstract nouns. Abstract nouns become abstract through the process of nominalization. A scientist takes a word from its verb form like *discovered* and turns it into a noun by saying *discovery*. In another example, the scientist will take an adjective like *significant* and turn it into a noun by using *significance*. Abstracting away from the action allows the scientists to develop theories.

Although understanding the process of nominalization is critical to understanding abstraction, it is also necessary to understand that the new word embodies all of the process and qualities of the word from which it was derived. It also summarizes large chunks of texts that occur prior to the introduction of the word in a scientific text. Data showed that when teachers explained their understanding of abstraction, they did not include an explanation of how the new abstract noun functioned in science language. Their attention was on the process of nominalization, changing words from verbs and adjectives into abstract nouns.

The following excerpt from a professional development session illustrates the teachers' struggle with understanding the concept of abstraction in science language. The science teachers read an article Beyond the Fab Five (2008) in which Fang explains why science language is abstract and how the process of abstraction happens. Billie attempted to summarize her understanding of abstraction from the reading. Her initial understanding focused on how the words change during the process of abstraction. Also, she understands the author's explanation of why abstraction makes reading science challenging for students.

> Saying that a science text is abstract like the author said is talking about how they say that the technical vocabulary nouns are derived from what we would express normally in the concrete language and made fancier. So the students have a hard time connecting the every day life to that word they know because it's not quite the same as it would be in real life. (PD5-12/09/08)

After Billie shared her initial reaction to the reading, Brad responded. He explained what he read in the article about abstraction and related it to how his students were understanding words in the texts they were reading in his class. When he communicated the classroom scenario, however, he focused not on the concept of abstraction, but on his students' inability to understand the word in its verb or noun form.

> And it happened actually on my test today which – we're doing ecology. And you know we were doing food chains- and there was a picture for the question. And I said, 'In the picture depicted above,' Well, what's depicted? It's shown, you know. And the kids know the food chain. Nobody got it wrong out of a hundred of them. But some of the kids had a hard time because depicted is not a normal word that you hear in everyday life. 'Oh, look at that depiction on the TV. (PD5-12/09/08)

From this statement, Brad demonstrated understanding of two concepts from the article. He is aware that the words need to change because he has used the word *depicted* in its verb and noun forms. He also understood that students struggle with science reading because the language is different from the everyday language that students use.

As discussion continued, I directed teachers to review the article about how the author explained abstraction. Bette responded with her interpretation of what Fang said about abstraction in science language. She explained:

> Another thing with this idea of abstraction in one of the examples he gives is they [scientists] take words like adjectives. You say, "That is – that is a

> significant," – using significant as an adjective. Let's say, "That this storm made a *significant* impact on the community." They know it made a big impact. The significance of the storm was – so what we've done – you can say, it's more natural to say, "The storm made a *significant* impact on the community." That's report –that's how you might hear reporting. But you might write about it. You want to be more assertive in your writing as a scientist because you want people to believe you and so a lot of scientists will take – instead of saying, "That storm was – that was a *significant* storm." They might then talk about, "The *significance* of the storm. Now you've taken that adjective – you've switched it into a noun. Well in our narrative writing the nouns of our sentences, the who's and the what's are primarily peoples' names, places and you know *I, he, she*, your pronouns. In science they're abstract *the discovery*, *the significance*. (PD5-10/09/08)

This statement demonstrates how Bette's initial understanding of abstraction focused on changing the words from adjectives or verbs into nouns rather than understanding how that new word derived from the verb or adjective packed within much information. This allows the writer to further develop theories only having to use one word (i.e. significance, depiction, discovery) to refer to an idea described previously in several sentences.

After the science teachers' initial response to the concept of abstraction, it was clear that they were struggling to understand how abstraction played a role in science language. Their misconception of the term was interfering with their understanding of how abstraction was used in science language. In addition, they were basing their understanding on knowing how to make words abstract.

During the follow-up professional development modules, I modeled strategies to use in the classroom for science teachers were shown how the abstract nouns in science functioned to help scientists build theories and arguments. To learn about abstraction, the teachers practiced using the abstraction strategies to analyze how the abstract nouns were used in science writing.

Sentence completion was the first strategy introduced to encourage their understanding of abstract nouns. The teacher locates a reading passage that contains an abstract noun to perform sentence completion. That abstract noun is then removed from the sentence, and the teacher presents the passage to the students with a blank space for the missing word. Students should be able to use the text around the word to make an educated guess at the word that the author used in the sentence. Then, the teacher should discuss how the new abstract noun packages the information prior to it in the sentence and allows the writer to continue to talk about the idea further by using just one word.

The following excerpt from the professional development module illustrates the teachers' experience learning about abstraction. The teachers were presented with the following sentence.

> During the winter humpback whales head north for cold waters of the Artic. ________________ is long and dangerous. [sample key: the journey}
>
> **Billie:** Does it have to be one word?
>
> **Facilitator:** No.
>
> **Brad:** Migration.
>
> **Bette:** Migration's what I came up with.
>
> **Billie:** The journey.
>
> **Facilitator:** The journey?
>
> **Billie:** I said the trip initially, but then I had to go out of ninth grade into.
>
> **Mona**: It's. I thought it's. It's.
>
> **Facilitator:** Somebody tell me your thinking – how did you decide? What did you look at to some up with what this word was?
>
> **Billie:** Well, they said head north. So they're taking a trip or a journey or.

Patsy: Mm hmm.

Lisa: Heading north or south is usually a migration.

Patsy: They're moving.

Lisa: In animals a movement prompted by a change in weather.

Facilitator: Okay. Tell me what this makes you do as a thinker? Thinking about language. Like let me see your mind going through. Why do you think it would be useful, not useful when you're doing this? This exercise I just asked you to do.

Brad: Cause you actually thought in depth – I actually pictured the whales going up the coast and like alright, what is that word? Yeah, they're swimming, of course. That was the first thing that came. And It popped through my head, too if I was four. They're migrating. And it's just a process of elimination to get the most specific word that fits in there to make it clear.

Billie: The key thing for me on this is I immediately think onto migration because of the head north. That just smacked me right upside the head that there was a very specific word dealing with what should go in the blank because heading north or heading south indicates by its very nature the word migration.

In this scenario from the professional development module, the teachers were wrestling with how to find the appropriate word to complete the sentence. In this example, the word *journey* is the appropriate word from the text. In order to determine that word, the teachers had to synthesize the information prior to the abstract noun. They needed to think of a word that meant the *humpback whales head north*. The new word *journey* then represented that notion of the whales moving.

After completing this exercise and four other examples, Brad stated that he still found it challenging to pick out the words when he was looking at his own textbook. "I look at the textbook and I just think they do not use a lot of abstractions, they make it simple so it is hard to find the real science like writing" (PD5-12/09/08). Brad had brought his biology text to class so we opened the book to search for an example. We examined the following passage:

> Sometimes a population grows more rapidly than the available resources can handle. Resources that are needed for life, such as food and water, become scarce or contaminated. The amount of waste produced by a population becomes difficult to dispose of properly. *These conditions* can lead to stress on current resources and contribute to the spread of diseases that affect the stability of human populations both now and to come. (Biggs et al, p. 92)

I directed the teachers to think about the words *these conditions* in the third sentence. The writer summarizes what was introduced in the first three sentences and then uses the words *these conditions* to condense the information. This allowed the writer to develop a line of reasoning about what *these conditions* will do to the human population.

In the professional development module, I continued to emphasize that abstraction was important in science language to allow the writer to synthesize information into a theoretical entity so the writer can build upon the idea and develop theories and arguments. The following example illustrates how I called attention to the purpose of abstraction in science language during the training modules. Teachers were presented with the following excerpt:

> At the beginning of the century the human genome project made another great leap forward by completing the enormous task of reading the letters that make up the instructions contained in our DNA. ______ marks the start of a process that one day will allow humans to understand completely how DNA makes us all human beings but also makes us unique individuals. [sample key: The discovery]

Brad: This. That what you guys got, too?

Bette: Well, actually I said this task.

Facilitator: This task. Okay.

> **Billie:** I said this accomplishment.
>
> **Facilitator:** This accomplishment?
>
> **Lisa:** I said mapping the genome.
>
> **Facilitator:** Okay.
>
> **Casey:** I went right to the human genome project marks the start of a process that one day –
>
> **Facilitator:** The textbook says this discovery. So you're all in the right ballpark. But again, look at how many different ways there are to say this discovery. Discovery is an abstract term because discovery means all of this [points to previous part of reading page] The scientists, in order to build their chain of reasoning, told you this, and then turned it into this discovery. And now they are going to be talking about that. – that's what I mean about abstraction. It's not just this thing that you can't see. *A skeleton*. You know or *a cell*. It is a word that takes and packs a lot of information into it. This discovery can mean a lot of different things. You have to be able to understand that this word represents all of this. (PD5-12/9/08)

These examples illustrate how the teachers learned to think through the sentence completion exercises. In both examples, teachers used the language around the word to think about an appropriate word to fill in the blank. I continued to emphasize that this sentence completion exercise was different from the traditional fill-in the- blank exercises. I closed our session with the following review of the purpose of sentence completion exercises.

> So again, you were forced to read this, reread this, what kind of word would go in there? Again, the focus is on language. So you see how this is an exercise in language? The purpose of the sentence completion is not to just spit out a vocabulary word. That's a different purpose. The purpose of these exercises is to get kids to think about the language. (PD5-12/09/08)

Despite my continued emphasis on the linguistic approach to these lessons, teachers struggled to understand the concept of abstraction. As teachers examined the concept of abstraction in science language, discussion returned to e the process of making words abstract in science. Prevalent themes in teachers learning about abstraction included focusing on the strategy of how a word was changed instead of understanding why a scientist might need to use abstraction and how the technique of abstraction in science writing contributes to scientific writing. The teachers struggled with choosing appropriate words for the sentence completion exercises and with leading the classroom discussion to focus on the linguistic aspects of the text.

Data revealed that the science teachers' understanding of abstraction varied. The idea of abstraction in science language was largely unfamiliar to this group of science teachers, and they struggled with their understanding of the concept. One trend in the teachers' explanation was a focus on nominalization. Both Patsy and Bette describe their understanding of abstraction by explaining the process of nominalization. In her final interview, Patsy stated:

> The fact that they [scientists] convert words, and they put them in a different way – the nominalization- they convert verbs, and processes, and adjectives into a noun. You know, *the discovery,* from discovered. This concept, this word is used, often used in science. It never dawned on me that those are abstractions. I just didn't totally recognize that at all. (FI-PB-5)

She continued to explain her struggle to make sense of the concept of abstraction.

> And that was the hardest, I think, for me to get a handle on was the fact that they [scientists] convert words, and they put them in a different – the nominalization they convert verbs, and processes, and adjectives into a noun. And because I'm familiar with science and have the good background, I just breezed right through all that and didn't think it'd be a problem for anybody. (FI-PB-5)

Bette also focused on the process of nominalization in her final interview to explain her understanding of abstraction.

> I think its called nominalization – that's a word I had to learn – where we take a verb and make a noun, and in science, they do that all the time. It's very abstract. Not tangible, not something that my students can readily see, like *significance*. The words *concept, significance, idea*; all of these terms are so abstract. They're trying to wrap the student's mind around a

> particular thing that was maybe discussed in the book, but they use an abstract word to describe a full idea. That was new to me. (FI-JB-6)

Despite the science teachers' struggle to understand abstraction, data showed that their participation in the workshops did raise their awareness as to how the abstract nouns could impact students' comprehension of scientific texts. In her final interview, Casey said:

> Now, I'm kind of more aware of the fact that there's a broader meaning to this term [abstraction], it has to do with the fact that we present a concept to them [the students], and then we refer back to it in science reading and writing as one word. They have to have assimilated a whole concept, and now, associate it with that one word. (FI-MC-6)

Bette explained how it was a surprise to her to think that students would struggle with words that were abstract.

> Well, that is something that was kind of new to me - You know you don't realize that you've somewhere along the way you've learned that. Like I think one time in a meeting I just mentioned like I just feel like I've always known that you know. The idea that my English teacher which I think supports that English teachers teach verb tense noun, so like the idea that something is an adjective like significant. But we have the significance of something, so that's the noun form and for me that came very easily. I was in English, and I did well - Out of there, so just the idea that kids would struggle with abstraction in that sense. That concept could be referring to some idea explained earlier in the passage. It just to me as an adult teacher, I just didn't think that kids would have to struggle with that. (FI-JB-7)

> Billie expressed that she was more aware of abstract words now when she prepared lessons and read science materials. She commented during an informal meeting that she was actually looking for abstract words in the textbook so she could call the students' attention to the words while she was teaching.

> Actually, now that I'm aware, especially with abstract words, I try to find them in the text and make sure that my students are aware of them as well. I have found myself saying, 'Oh, there's an abstract word' and then talking about what that word means with my students. (IM-JTB-3)

Casey also sent a lengthy reflection on her understanding of abstraction in science language in an email communication. She explained that the abstract words in science might summarize a concept explained in greater length in a previous portion of science text. Casey also discussed how the use of abstraction in science impacts student learning.

> Abstraction makes reading science content difficult because it increases the density of information. Students must be able to associate an entire concept with one word such as ‘condition’. Consequently, a lot of new and often foreign information can be packed into a relatively short reading assignment. This alone would present a challenge for students, but coupled with the new technical vocabulary and concepts with which they may have no previous knowledge, students can be overwhelmed. (EC-MC-11/05/08)

Casey closed her email with a reflection on what the understanding of abstraction means to her teaching. She explained that the way she prepares her lessons and teaches her students changed as a result of her participation in the study. Casey still connects her new understanding of abstraction to her previous understanding of what she thought about when she considered how something in science was abstract.

> My initial thought about abstraction as it relates to my own teaching of science is that I have had an incomplete view of what abstraction in science reading encompasses. Previously, I had thought that we teach abstract information in science because the students can not “see” concrete examples of many of the concepts that we teach. For example, when I present the sliding filament theory of muscle contraction to my students, I know it is difficult for them to grasp because it involves microscopic structures which they must mentally picture using diagrammatic representations from the text. However, I did not realize that the act of reading science content itself involved abstractions because it requires students to associate major concepts with one word. (EC-MC-11/05/08)

Data clearly showed the science teachers struggled with their understanding of abstraction in science language. Although Billie and Casey made progress in their understanding, two other teachers demonstrated limited change in their understanding.

For example, Lisa, in particular, still focused on how ideas in science were abstract versus the language. In her final interview, Lisa discussed concepts being abstract and did not address the issue of science language.

> Some of the concepts like the ADP cycle or genetics, while students get the idea the functioning of it, it is so abstract they can't eat it, they can't date it, they're not gonna see it on TV, it's not physical, it's not tangible, it might not impact their lives. Therefore it is a concept, it is abstract, it is distant. (FI-VL-8)

Learning about abstraction was challenging for the science teachers. Prior knowledge of the word abstract in the context of science interfered with the teachers' understanding that abstraction in this context referred to science language. In addition, the science teachers focused their attention on the process of nominalization in their explanations of abstraction. While nominalization is an important piece of abstraction, the science teachers struggled to understand the purpose abstraction in writing about science.

Density

Science language is dense because sentences contain long, complex nouns that include a high concentration of information. A simple noun may be expanded through the use of grammatical tools such as prepositional phrases and embedded clauses. This expansion increases the lexical density of a science text; in other words, this expansion makes the text more challenging to read. This process however, enables the scientist to be precise as well as concise in developing arguments or theories.

The science teachers rated their understanding of density the lowest out of the four topics covered. The average rating of understanding on a scale from 1-5 was a 3.6. The science teachers struggled to understand how density contributed to the development of ideas in scientific texts.

Two themes were present throughout the data when teachers discussed their understanding of density in science language. First, the teachers described density in terms of how much information was in science text versus how the use of lengthy, complex nouns made the science language dense. This in turn makes it easier for writers to include much information in a single sentence. Next, the teachers were apprehensive about their knowledge of the language structures (e.g. prepositional phrases, embedded clauses, head nouns) that contributed to making the lengthy, complex nouns. Therefore, they were hesitant about their ability to teach their students about density.

During the initial professional development module, teachers were introduced to the concept of density by reading the article *Beyond the Fab Five* (Fang, 2008). In this article, Fang gives an explanation of density and includes a brief explanation of lexical density and examples of how long complex nouns contribute to the density of science language. He also discusses how the long, complex nouns allow the author of a science text to include much information.

The science teachers immediately agreed that science language was dense. However, their initial perception of density was focused on information load and why that information load could make reading science difficult for students. For example, Bette shared her response to the article on density in science language.

> I think that's one of the major areas [density] in science that throws someone off or causes someone to just not really care for science because it's too dense. They feel it's overwhelming, and it's hard to wrap their minds around all of the information loaded into a sentence. (FI-JB-3)

Lisa contributed her thoughts on density in science language to the discussion. She agreed with Bette that science language was dense. She also discussed the issue of density compared to the amount of information in a text and did not address how the layers of clauses and phrases lengthen the noun, making it more difficult to comprehend. Lisa said:

> Science is profoundly dense. Packed with words they [students] are not familiar with. Loaded with terminologies. Distant from their daily lives. They say, "This is too hard. Too many words. I don't get this." The article said nouns are the most powerful grammatical structure that contributes to a texts' informational density. The more words you have the denser your text, the more nouns you have the denser the text. (PD2-9/16-56)

Although Lisa recognized that nouns contribute to the informational density of the text, she missed that the reason for this is due to the length of the nouns and not the quantity of the nouns. The idea of lengthy, complex nouns was new to the science teachers. Instead of focusing on the how the nouns were structured, the teachers focused on the number of nouns in a sentence.

In the next step of the introduction, teachers were directed to find examples of density in their textbooks. I called their attention to examining passages that had long nouns like the examples in the articles. Casey shared an example from her anatomy textbook, commenting that it was dense because of the technical terms. However she was unsure if it was relevant to the article's discussion about long nouns.

> I'm not sure if mine is so much density as more technicality because so many times in anatomy they define a word using these other technical terms. My sentence is, *The innermost sensory tunic of the eye is the delicate white retina which extends anteriorly only to the ciliary body.* (PD-2-57-MC)

Casey's sentence was dense, but not due only to the number of technical terms. Her sentence was dense because of two long complex noun groups. The first group is prior to the verb in the sentence, *The innermost sensory tunic of the eye*. In this case, the head noun is *tunic*. The premodifiers are the determiner (*the*) and the adjectives (*innermost and sensory*), and the post modifier is the prepositional phrase (*of the eye*). In addition, another long noun is *the delicate white retina which extends anteriorly only to the ciliary body*. *Retina* is the head noun followed by the embedded clause (which extends anteriorly).

After Casey shared her sentence teachers were in complete agreement that the sentence was dense. Bette exclaimed, “Oh, that's definitely dense.” (PD2-9/16/08-57) When probed for why the sentence was dense, however, teachers’ commented on the number of words versus the two lengthy nouns. Patsy commented:

> This idea that there's more words per sentence, more nouns per sentence, more ideas then in like the Arthur text which was short little sentences with not a lot of big concepts or conceptual words. There is a lot of information and bigger words that student might not know in the science text making it harder to read. (PD2-9/16/08-58)

Lisa concurred with other teachers’ thinking about density and shared an example in her marine science textbook. She explained that when the authors clarified processes in marine science, large amount information was packed into one sentence. She read from her marine science textbook, “The current flows around the periphery due to *a balance between ecma transport trying to push the water to the center of the base and the high point in the center holding the flow away.”* (PD2-9/16/08-56)

When asked to explain why she thought it was dense, Lisa stated that the sentence was dense due to the number of prepositional phrase in the sentence.

> You've got a couple of nouns in there but they put all these prepositional phrases before it, after it, all around it. They've made that phrase very dense. And that just shuts the kids down and they just kinda go, ‘Oh, can't read that. Don't understand it.’ (PD-2-56-VL)

Lisa is on the right track in recognizing that prepositional phrases contribute to the density of the sentence. But the next step is identifying *why* they make it denser. In this case, the reason this sentence is dense is due to the long noun *a balance between ecma transport trying to push the water to the center of the base and the high point in the center holding the flow away.* The head noun is *a balance* followed by *between ecma transport* (prepositional phrase)*trying to push the water*(embedded clause*) to the center*(prepositional phrase*) of the base and the high point* (prepositional phrase) *in the center*(prepositional phrase*) holding the flow away* (embedded clause). This long noun phrases allows the writer to pack a lot of information into one sentence that otherwise would need to be expressed in multiple clauses.

Teachers identified examples of density in their textbooks, but had difficulty explaining why the text was dense. Even after I pointed out where the long, complex nouns were in the sentences, the teachers' understanding still remained focused on the amount of difficult words in the sentence.

The data from the first professional development session indicated that the teachers' initial understanding of density was based on their previous notion that science language was dense because of the number of technical words or the amount of information. While both of those conditions contribute to the informational density of a text, the idea of how the structure of the science language impacted informational density was a new concept to this group of science teachers. The idea of lengthy, complex nouns was unfamiliar and the teachers initially found it difficult to identify these types of nouns in science writing.

When we met for the next session to discuss density in science language, the teachers had an opportunity to practice identifying long, complex nouns. To introduce the idea of long, complex nouns, the science teachers practiced identifying noun groups. For example:

> *Mutations* in a target *protein* that affect binding of an *antibiotic* to that *protein* may confer *resistance*.

In this sentence, the long noun group is *Mutations in a target protein that affect binding of an antibiotic to that protein.* The head noun in this sentence is *mutations*. The prepositional phrase *in a target population* is a postmodifier which is followed by an embedded clause *that affects binding of an antibiotic* which contains another prepositional phrase *to that protein*. This process of adding information to qualify the noun makes science text more challenging to readers.

The science teachers completed several similar exercises and picked out the simple nouns and the verb in the model sentences. In addition, the teachers identified the long complex noun groups of sentences. However, when the discussion about density in science language included identification of sentence parts, teachers were not as comfortable with their knowledge level. Billie expressed her uneasiness of talking to her students about grammatical features when she said:

> Well, English could be very helpful now that I am learning about this stuff. And it's so funny because I tease my students. You don't realize, oh, I'll never do this again. And then somewhere down the road you're like, if I only had paid attention to English. (IM-JTB-4)

During an informal conversation with Casey, she expressed her doubts about not having enough grammar knowledge to teach students about density.

> The density and just understanding it. Breaking it down into the clauses has just been the hardest thing. The topic is not necessarily a difficult topic. It's just trying to do it right and identify the right parts of the sentences. (IM-MC-FN-02-13)

Later in her final interview, Casey still felt uncomfortable with her understanding of how the language structure impacted the density of a science text.

> I think one of the challenges that I faced had to do with, again, not feeling as comfortable with the English component of it. For example, when we were doing the sentence combining or we actually did it the other way, too, where they actually wrote the sentences down and there were just some of the terms for the different parts of a sentence, the clause and such that I might not have remembered. I think that was one of the challenges. (FI-MC-6)

In her final interview, Bette echoed Casey's concern about having enough knowledge of the language structures in order to effectively teach density in science language. She explained:

> I know that it's dense. All you have to do is look at the textbook. But with the whole density idea, some of the aspects that I was not as proficient with were the identification of the clauses, and the application of the lexical density formula. (FI-JB-3)

In her final interview, Patsy also expressed her apprehension about being able to detect the grammatical structures in science passages.

> The actual breaking down of the clauses and trying to figure out what exactly is going on. We have a participant, and the circumstance, and the process. I can see that but I just need to strengthen my language arts skills to be able to use that more comfortably myself in the classroom. (FI-PB-8)

To address the teacher' misunderstanding of density, I relied on informal meetings with the teachers to assist in their planning for the lessons. For example, Billie expressed difficulty in developing a lesson on density so we met to review the ideas from the professional development session. When she looked for a sentence with a complex noun group in her textbook, she determined that the text was simplified for students.

> I was reading through their book, because I was looking for a long sentence that crammed a lot of stuff in there where we could break it down. And this

book isn't that way. And I figured out why they like this book because it's in short little chunks, not a real good example of science language. (IM-JTB-1)

Billie seemed discouraged in planning the lesson because she could not find a good example to use in her class. Together we read parts of her textbook and searched for examples that she could use for her lesson.

Facilitator: Do you want to look at doing one of the density things if we found a passage that interested you or that you saw that would fit?

Billie: Well, I would have to read through this one [another textbook], maybe it is better.

Facilitator: If your purpose is to try to explain density, then maybe not get so hung up on the fact that it's [the material] is over their head, but that they understand how these scientists make big nouns in writing. Does that make sense? So, for example let me just glance at one of these right now and see. All right, this sentence says – *many types of nuclei are held together permanently and are stable, however, there are many other types of nuclei that are unstable*. So you could do just like a five minute thing to introduce the idea. Let's look at this sentence – you could start one day and say 'I'm going to take just a couple of minutes and I'm going to show you a sentence that shows one way that scientists make reading so dense." Then show the sentence and point out how long the noun is. For example, in this sentence you could underline the noun group *many types of nuclei and many other types of nuclei that are unstable*

Billie: And that would be fairly easy to do, because there's plenty of those in there. Go through; pick them out, because we can do that even as our bell activity tomorrow. Start doing it maybe not with – like you said, do it with the short sentences and lead into the bigger complex nouns, just to get them to start seeing the nouns.

Facilitator: You could model it for them, like for one day or two days, and then the next day say 'Well, let's try some of these for our bell activity on our own. I'm going to put a couple of sentences up here on the board about radioactivity. See if you can identify in one column the simple noun and then in the next column the complex noun that serves as the subject of that sentence.

Billie: Yeah, that's pretty easy to do. I think it was struggling with the – and I have an example because I know it was there with the ______ and the other –

Facilitator: I think the most important thing is they just start to recognize how science language is dense. And it's dense because one of the things that scientists do is they take these nouns, or these subjects of sentences, and they make them really long. Now, we can say they make them real

> long, because they add embedded clauses and prepositional phrases and determiners. I think that you can get to that point eventually if you want to, but if they can just recognize that all this stuff is part of the subject of the sentence and they find the simple noun- then that is a good place to start.
>
> **Billie:** And I think for at least with the ninth graders, recognizing that is the whole subject, because they are used to that novel reading where it's Dan, Joe, the dog. And it's real short. And part of this lengthy process is that they make it longer in their writing, so I think that would be good to do with them and see what the outcome of it is. See if they start recognizing it on their own. That whole thing is a subject- that would work. (IM- JTB- 9-12)

Billie believed that the concept of density in science language was important, but she found it challenging to find material that contained long, complex nouns in her textbook. In addition, she was concerned that she did not have the background knowledge in English to discuss grammatical features such as embedded clauses. Meeting individually with Billie seemed to convince her that she had the knowledge base to introduce the idea of density to her students. Even though the goal is to move more deeply into identifying the long, complex nouns in the entire sentence, Billie felt comfortable at the beginning by looking at them in place of the subject of the sentence.

Two of the science teachers in particular did not feel comfortable with the concept of density in science language and therefore rated themselves low on their understanding. For example, during his final interview, Brad rated his understanding of density:

> So as far as density is concerned, which is your third, I'd probably say – I'll give myself a two, but probably a one, because it's just – some things are just – they're hard for me to see, and that is just – I definitely – that's why I said I would like to work further on it, because the more understanding I have at the – the more chances I will use it and I like to use new – new techniques, keep fresh in the classroom. The density and just understanding it. Breaking it down has just been the hardest thing. The topic is – is just probably – not necessarily a difficult topic. It's just trying to put it – Right. And it's completely out of my comfort range. (FI-MB-4)

Billie also acknowledged that she was not comfortable with her understanding of density. She described how she questioned her ability to address density correctly in the classroom,

> I put it [density] as a three, and I think that's cause I understood it, but I didn't – I wasn't able to, you know, pass it along, per se, as well as I would have – I would have liked. Like, it wasn't a comfort zone for me. (FI-JTB-4)

Bette had the highest self-rating on density. In her explanation of her understanding, she addressed the issue of complex nouns

> Density, probably a four. I think I did pretty well with this. Just understanding how dense some sentences are in science language, how they have complex nouns, seeing all the prepositional phrases that are used and when you really break it down and understand – Basically, understanding, what's the root – what's the main subject and the root verb. Then, understanding how that links. Beyond all the prepositional phrases in between, how that links to the main idea of the sentence. (FI-JB-4)

Although the science teachers readily agreed that science language was dense, they found it challenging to understand how language structures impacted the density level of a science text. The science teachers contributed the issue of informational density to technical words and the amount of information in a short passage of text. It was challenging for them to deconstruct the lengthy complex nouns and understand how they contributed to the information load of science texts. Although teachers were successful in identifying the location of the complex nouns in a sentence while working together in professional development sessions, they did not understand how to identify the layers of the noun to explain how the noun was expanded. Rather than thinking about how long nouns contribute to density and why they are necessary in scientific writing, the science teachers' understanding was influenced by their belief that they did not have the grammatical knowledge to talk about the embedded clauses and prepositional phrases with their students.

Genre

Science language is comprised of multiple genres. Genres are organizational structures that frame information in scientific texts. These structures serve a particular social purpose, e.g., to inform, to instruct, to explain, to discuss, et al. According to Veel (1997), there are seven major genres in science: procedure, recount, explanation, description, report, exposition, and discussion. Each of these genres has its own structural and grammatical features.

The science teachers reported an overall understanding of the topic of genres as a 4.3 on a scale of 1-5 with 1 being the lowest level of understanding. Through their participation in the professional development modules, the teachers' understanding of genres developed positively.

During the initial introduction to the topic of genres, teachers had an opportunity to cooperatively analyze sample passages and identify the genres. Teachers were presented with a matrix that delineated the purpose and grammatical features of each genre. In the following example, teachers analyzed a selection. They cannot decide if it is report or discussion. As they discussed this example, their focus is more on the understanding of the structures of the genres versus the grammatical features. I tried to draw them to looking at the grammatical features as they analyzed the text. Sample text:

> The animal kingdom is made up of many different animals. In a way they all need to work together in order to survive. Each animal needs another animal or plant for survival. It starts from the smallest of animals and continues on, all the way up to the largest.
>
> This togetherness is called the food chain. The smallest animals in the chain will be the ones that do not eat other animals, but eat plants and fruits, vegetables, and seeds that come from plants instead. These are called ***herbivores***. The rest of the animals in the chain are called either

carnivores or ***omnivores***. Carnivores eat only meat, which, of course, is other animals. Omnivores eat from both food groups, so that means they eat what both carnivores and herbivores eat. Humans are omnivores (from http://www.associatedcontent.com/article/375038/homeschool_science_lesson_plans_food.html?cat=25

Transcript of discussion on genres:

Facilitator: All right, let's talk about that one then. Why did some of you label it as report

Bette: Because it's explaining how something's put together, how the animal kingdom works.

Lisa: Plus, it was a general statement. *The animal kingdom is made up of many different animals.* Reports have big general statements. Then they talk about that statement.

Bette: It's explaining so many different terms- omnivore, carnivore, food chain.

Billie: It is also the description of various things, what togetherness was, what smallest animals are. Report says that there are various descriptions in it.

Casey: Well, let's look at the special purpose of each one.

Bette: Okay, I didn't look at that, I looked at text structure.

Billie: Yeah, the structure, let's start with special purpose and see. The social purpose of report is to describe attributes, properties, behaviors of a single class or entity in a system of things. So your text structure –

Brad: It's not report; it just puts it right out there because this does not just describe something.

Casey: Yeah, this is different.

Brad: Because it talks about herbivores, omnivores, carnivores. If it was a report, it would just talk about the behavior of carnivores or something like that. Don't you think?

Lisa: No, because it's unifying the animal kingdom.

Casey: Yeah, that's what I would think. It's talking about the relatedness of the food chain.

Billie: And the text structure of report is a general statement and then a description of various aspects of things. The explanation's social purposes is to explain how something occurs or is produced and the text structure is phenomenon identification and explanation sequence.

Lisa: Where was the sequence?

Mona: Oh, come on!

Bette: Herbivore, carnivore, the rest are carnivores or omnivores, omnivores eat from both food groups.

Lisa: That's not necessarily a sequence.

Mona: It's not necessarily not a sequence though. It does not have to say first this then that.

Bette: I'm still holding out for report.

Facilitator: Let's look at the grammatical features. What do you notice?

Bette: I don't think it explains how something is produced. It is just reporting.

Lisa: Yeah, 'cause you've got the little paragraph which is your general statement about the animals and then you go to the description of various specs of the animal kingdom. That's why I'm rooting for report. It is just reporting the information.

Bette: Yea and I don't see any logical conjunctions, what are those again?

Facilitator: The logical conjunctions which are a part of science are like *however, hence, therefore*. Your logical conjunctions are the ones that connect the ideas. You see those more when they are trying to explain something, connecting the ideas. Your *accordingly, still, likewise*. It's that conjunction that brings that sentence before it and connects it to that next sentence to build usually argument or discussion.

Billie: Ok I am still saying just all over it's an explanation. (PD-b03-13)

The sample passage was a report genre. This was a report genre, not an explanation, because it does not explain a particular phenomenon. It simply describes several aspects of the animal kingdom. As teachers continued to analyze the genres, they were able to discern between the types. Throughout the professional development session, we continued to look at samples and compare what we were reading to the chart that outlines the characteristics of each genre.

After practicing together in the professional development module, the teachers were able to identify the genres of procedure, recount, report, and explanation, but they felt unsure about how to differentiate between discussion and exposition. Teachers expressed that the genres of exposition and discussion were less familiar.

When probed about their understanding of genres, the teachers used their prior knowledge and familiarity with the structures to explain their understanding. The teachers did not discuss the genres in terms of their grammatical features, with the exception of one teacher. For example, when Casey explained her understanding of genres, she reported that she relied on looking at the chart distributed in class to differentiate between the genres. Casey thought that procedure and recount were easily recognizable due to the frequency with which she used those genres in her classroom already. She explained that while report and explanation were closely related, she could identify the differences once she reviewed the information about the genres. However, she struggled to differentiate between exposition and discussion.

> I certainly feel comfortable with some of the genres, like the procedures, the steps because we use that so much, and the explaining. Some of them, there was like a fine line to be able to tell the difference and I'm not even sure I fully can discern between them. (FI-MC-5)

Although the teachers expressed some confusion over discerning between the genres, they were receptive to the concept and willing to work on understanding the distinctions. Michael explained his understanding in the final professional development session.

> One thing I pulled out of this was the first four (procedure, recount, report, and explanation), our students see procedure, they see a recount, they see

> report and they see explanation all the time in the writing, but they're not too familiar with how to read exposition and discussion. In my class they do a paper on endangered species and I have them write about a genetic disorder, but it's just writing a bunch of information down and giving it to me. I think what I am going to do next year is ask should the gray wolf be released? Is it a good thing that it is back in the area or do you agree with the forum? Pick a side and write me a paper that way. This way, students are forced to write an exposition paper. And they will probably have to read some discussion and exposition to get the information. (PD-MB-03-09)

Bette explained her understanding of genres in her final interview. She felt that the genres gave her a good way to help students think about the author's purpose.

> I think it's great that you discussed genres with us. Again, the main point that I got from what you had explained to us is there's a purpose. What is the author trying to tell the reader? Is there bias in there? What's the purpose of that writing? (FI-JB-8)

Another theme in the data showed that teachers perceived that teaching students about the genres in science language was useful to their science teaching. For example, Brad commented during his final interview:

> So as far as genres, I really like genres. I'm a five with that, because it's just – it's important to teach kids what something is saying or the type of writing that it is and the different styles that you see. And they should be able to – you know, if they can identify it, it would probably help them understand it a lot better. (FI-MB-3)

In another example, Patsy also indicated that she found the information useful for working with her biology students.

> When I started looking at the genres, I thought, 'This has science fair all over it.' And the fact that I could help my students' understanding by having a better concept and better grasp of genres became apparent to me once I saw how many were used. (FI-PB-4)

In summary, the science teachers understood how genres were used in science writing for various purposes. Their prior knowledge of genres such as report and explanation facilitated their willingness to learn about the other genres described. Their focus in learning however remained on the purpose of the genre and not as much attention was given to the grammatical features that identified the various genres.

Teaching the Specialized Language of Science in the Classroom

This section details the experiences of the science teachers as they attempted to integrate the concepts from the professional development modules into their teaching routines. Both barriers and facilitators of the integration process are described for the four topics: technicality, abstraction, density, and genre.

Technicality

The science teachers implemented technicality strategies in their classrooms that were presented during professional development modules. Teachers cited level of comfort, proximity to strategies already used, and prior knowledge that technical words were important to understanding science as reasons they would use strategies that addressed technicality in science language. For example, Bette commented, “I knew that vocabulary was huge in science, so that’s just something I used to always work with my students on just because I know it’s so important from my medical terminology class and just experience before, as a student” (MT-JB-6).

Because it was familiar, the science teachers perceived the implementation process as easier for the technicality strategies. Bette commented in her midterm interview that, “Technicality was a lot easier because it was more vocab-centered” (MT-JB-1). Teachers could envision how the strategies could be a part of their teaching routines. Brad shared how he planned on using the strategies for technicality in his classroom: “I like breaking down the word and doing the suffixes, the roots, and the prefixes, and I think in my journals next year, every day is going to include breaking down a word from the chapter to help kids understand the vocabulary” (MT-MB-5).

In another example, Patsy explained how she used an idea from the information about technicality to enhance a vocabulary strategy she was already using in her class. She was using logographs to have students analyze vocabulary words. In a logograph the students were directed to choose a vocabulary word and write its definitions, use it in a sentence, and illustrate it.

> I had already been doing some of the logo graphs but I enhanced that based on some of the techniques that we shared in the class about using synonyms and antonyms in the corners instead of just having them illustrate the word to get them more involved with the language of the word itself. (MT-PB-1)

In an informal meeting, Billie shared how she had already been talking to her students about how to break down words. When they came across a word in class like semi-conductor she would break it down into the parts. For example she said, "so I tell them, semi means half or partly and conductor means a material that allows electricity to flow. Therefore, semiconductor means a type of material that only allows some electrons to flow through, but not all" (IM-JTB-6). Billie said that prior to our meetings, she had addressed technicality spontaneously during teaching, however, now that she had learned about technicality strategies in the professional development modules she said it would be easy to make it more concrete for students.

> I think if I do it more often with them, like I do out loud we break words down all the time, just because that's something I've always done; trying to teach them, "You know this big long word, let's look at the parts of it." So if you don't know what it means, do you know what any of it means? And so when we did this [concept maps] in the workshop I tried it. I taught them like, "Look we did this already, we've done this. Do you know anything out of this word?" I mean we did it verbally, but putting the words on paper was a little more concrete for them. (MT-JTB-1)

Evidence from observations and interviews showed the teachers primarily used three strategies for technicality in their classrooms: (a) morphemic analysis, (b) concept maps, and (c) vocabulary think charts. Morphemic analysis involves teaching students how to identify meaningful word parts like roots, prefixes, and suffixes in challenging science words. For example, during an observation, Bette told her class, “You probably don't know what this word means but I bet you can figure it out because you know the prefix *bio*. You know the root word, *mass*. Let's take it apart and figure it out” (10/20/08). Bette used her knowledge of breaking words into parts to help her students understand the word *biomass*. In a later class, Bette used her knowledge of morphemic analysis again to encourage students to look at words with similar parts to see if they could discover the meaning of the word *monoculture*. She shared in a professional development meeting how she conducted this analysis of the word *monoculture* to get students to understand how the prefix mono- meaning one and culture- meaning the act of cultivating the land led to the meaning of the word *monoculture*- a farming strategy in which large fields are planted with one crop year after year.

> We used *monoculture* and they [the students] were able to come up with *mononucleosis* and all these other really big words you know *monochromatic*. They connected that with monoculture. Then seeing the word *culture*, the root word, they were able to just get a better grasp of that by thinking of *agriculture, horticulture*, words with culture in them. Just breaking down the words into word parts and then just getting an overall view of that definition by thinking about words they already knew was helpful. (PD3-11/4)

Patsy also integrated the technique of morphemic analysis in her classroom. She explained during a professional development meeting how she used the strategy of analyzing word parts to help students compare words that ended in *-ology*. She said,

> Next I did archeology/paleontology/anthropology- they could break down the *ology*- so then we started looking closely at the beginning- so now they will say “I don’t know this word’ but they will start to look at it and say can I figure it out You can get them [students] thinking really easily about prefixes and suffixes (PD4-11/4-3).

Two science teachers used the technicality strategy of mapping to help students understand technical words. Casey used a map to analyze the word parts of a technical term in her anatomy and physiology class. During Casey's observation she introduced the word *osteogenesis imperfecta*. Her lesson started with asking the students to read a story about a baby that had a fracture in her arm. The word *osteogenesis imperfecta* appeared near the end of the story. She wrote the word on the center of her overhead and asked students to do the same on their own paper. She then asked students to break out word parts they recognized. Students identified *osteo, genesis, im*, and *perfect*. Next, Casey asked students to brainstorm with a partner the meanings of those words. When the regrouped as a class, she added the meanings to her map. Next she asked students to brainstorm other words they knew that used those word parts. Finally, she asked them to "take a stab" at the definition based on the information on the map. See Figure 6.1 for an example of the map Casey developed during her lesson (10/27/08).

Following are some of the definitions students wrote down on their maps.

- Born with bone defects
- Defect of the bone in the process of forming
- Imperfection in one formation
- Defect of bone in the process of growing

In another instance, Lisa used the concept map to analyze the word *heterotroph* in her marine science class. She wrote the word in the center of her overhead and stated: "This is not a common word you use often. It is a word we use in science." She then tells students that they are going to analyze the word together. She asks who can identify a word part they know. One student says that *hetero-* is the prefix and she has seen it in other words like heterosexual. Lisa then writes the definition of *hetero-* on her overhead explaining, "*Hetero*- means different or other. We write that down on our map to try to analyze what the whole word means." She asked students to think about what the word part- *troph* might mean based on what they know about autotrophs. Another student says "something to do with feeding or eating." Lisa explained that the word part –*troph* refers to nutrition. She then wrote the formal definition above the word on her overhead- *an organism that gets food from foods they consume*. She then asked for examples and compiled the following list with students: humans, leopards, sharks, dolphins, crabs. Next, Lisa asked for non-examples, or *autotrophs*. The students compiled the following list: plants, phytoplankton, and algae. Next she told students, "Read in chapter 4 to find out what heterotrophs are like. What do they do? What is special about them?" After the reading, students report information to complete the concept map. Lisa added the following information to the side of the map: do not use sun's energy to make food, get energy from eating, can also be called consumers (10/20/08).

Another strategy presented in the professional development workshops was the vocabulary think chart. Patsy used the vocabulary thing chart to introduce the word *vestigial organ* to her biology class. Patsy put a copy of the think chart on the overhead and reviewed the process of using the strategy. She then asked the students to choose a word for analysis, "What word do you want to analyze from our reading last night?" One student raised his hand and identified the word vestigial organ. She wrote that as the target word. The she began the process of analysis by reading through each question on the chart.

The students started with their recognition of the word *organ* and knew that was a collection of similar tissues within the body. Next, they looked at *vestigial*. They identified that the *–ial* at the end of the word probably changed the root word into an adjective so they assumed the root word must be close to *vest* or *vestige*. One student opened a dictionary and found the word *vestige* meaning a small amount of trace.

Next, the students brainstormed words that came to mind when they looked at the word parts. They generated the following list: footprints, imprints, organ donor, carbon footprint. While talking about these words, students connected real life stories to their ideas discussing people they knew who had organ transplants or why they thought the idea of a carbon footprint- the leaving something behind- connected to the concept of *a small amount of trace* from the term vestige.

In the next step, the students looked at the word in context. One student read, "The organs of many animals are so reduced in size that they are just vestiges, or traces, of homologous organs in other species. These *vestigial organs* may resemble miniature legs, tails, or other structures" (Biology, p. 384). Patsy then led the students to paraphrase a definition. She wrote on the think chart "the mark of something that once existed."

Finally, the instructions request students to come up with the target word in a sentence that was scientific. One student remarked, "A theory exists that whales legs have become vestigial organs." Another student shared, "Animals can exist without vestigial organs." Still another student said, "The appendix is a vestigial organ because we do not need it to live." Finally, in closing Pasty asked the student to relate the word to a larger scientific concept. Students listed: evolution, Darwin, adaptation, survival of the fittest, natural selection, modifications (10/21/08).

Patsy, Casey, and Lisa each used a strategy from the professional development modules to teach their students how to analyze technical words in science. Casey used the mapping to analyze the word parts of *osteogenesis imperfecta* and determine the meaning of the word. Lisa used the concept map to support students thinking about examples, and qualities of the concept of *heterotroph*. Finally, Patsy used the format of the vocabulary think chart to walk her students through an in-depth analysis of the term *vestigial organs*.

Another theme surfaced in the data when the science teachers talked about their technicality lessons: student learning. When the science teachers perceived a strategy made an impact on student learning, they were convinced of the usefulness of the technique. Casey indicated that her students were able to apply the strategy independently after she had modeled it in class the day before. She liked how the concept map gave her students an opportunity to work it out on their own.

> I used the word parts where they broke the word into word parts and thought of other words they knew and I was really impressed with this technique because in anatomy I have always tried to get them to think about prefixes, suffixes, and roots but I never really used a graphic organizer like this. The next day for the bell ringer I gave them a word that they would not have known the meaning of *glucomenogenisis.* My standard level students had used genesis in the word the day before and they had thought about the *gluco*- then most of them came up with that it was the forming of sugar. I was very impressed. I think have them use this graphic organizer is better then me just telling them – I like to just tell them things- like this means this and this means that- and then move on- and it kind of goes. But, when they have to actually work with it I think they remember it. And I am going to use it a lot more. (PD-11/4/08-1)

Mona also perceived that her students were successful with using the concept map in her class. Although she thought it took a long time, she saw that it made a lasting impression on students.

> It is probably the longest exercise I've ever seen on one word. And again we're reviewing for the exams this week so when we got to that word the kids said, "Same place." The first one we did was isotope. Same place; that means it can have – it can't have different protons so it can't have different neutrons. Yes. So they got it. I know it took – oh my goodness it took time but it certainly was worth while because of the lasting nature of the impression that it made. It was really, really good. (MT-BM-4)

Patsy had tried the vocabulary think chart in her class. As she was reviewing for their test, she said she felt a shift in students' confidence level about the words they were discussing. When she thought about it she believed it was related to the students' participation in the word analysis with the vocabulary think chart.

> I, as the teacher, was wondering why these particular answers had caused such a change in their attitude, and then it hit me! These were the words (*vestigial organ/structures* and *homologous structures*) we had used for the word analysis strategies in class when we had just started the chapter- the Vocabulary Think Chart. They were so pleased with their accomplishment, having used the words correctly in the completion exercise that their confidence had carried over into their success in figuring out how to use *analogous structures*. We had not covered that word in class. The Vocabulary Think chart had really made an impact on their memory of the word we did in class. They made comments such as, 'We remembered doing the transparency on the overhead with 'vestigial organs' and 'homologous structures' in class.' and 'We figured out how to make sense of those words, and figured out for ourselves what analogous structures must mean.' (PD4-11/4/08-3)

The science teachers were excited to integrate technicality strategies into their teaching. Because teachers were familiar with technicality in science language and they perceived that it was easy to integrate into their teaching practice, they willingly attempted several of the ideas presented in the professional development workshops. The science teachers used morphemic analysis, concept mapping, and the vocabulary think charts. However, even though teachers were eager to use technicality strategies, it is important to note that the science teachers' main focus during implementation was on technical words that were specific to science and not on the common words that were used differently in science.

Abstraction

Data revealed that the science teachers struggled with the integration of strategies that addressed abstraction in their teaching. Data from classroom observations showed that the teachers had difficulty transferring the ideas from the professional development sessions into the lessons. Lessons were often focused on word level strategies instead of analysis of how the abstract words impacted the meaning of the entire reading passage. Three trends emerged in the data when examining at how teachers integrated abstraction into their teaching routines. The first trend showed that the science teachers focused their abstraction lessons on teaching students about nominalization instead of how to deconstruct an abstract word in context and discuss the functionality of nominalization. The next trend showed that teachers had difficulty correctly applying the sentence completion exercise that had been modeled in the professional development session. The third trend was that the teachers acknowledged that they were addressing abstraction spontaneously in their daily lessons.

The following three examples show teachers struggling with correctly implementing abstraction lessons into their teaching. In each example, the teachers focused more on asking students to rename or identify words instead of directing students to consider how the word was created and what processes or qualities are implicated in that word.

In the first example, Lisa developed a lesson that required students to change words that were abstract nouns into the verb or adjective from which they were derived. When she introduced the lesson, she explained to the students that "scientists take words that are verbs and change them into 'thing' words- nouns." Lisa then commented about how this can make science reading more difficult and if students learn to use the "tool of abstraction," they can improve their science reading. She wrote the word *consume* on the overhead and shows students how the word can become consumption. She writes the following brief passage on the overhead: "The shark consumes the food. This consumption of the shark involves eating seals and other marine animals."

She began the discussion by asking students to locate the words that are similar. After the students identified the words consume and consumption, she reviewed how scientists change words from action words into thing words. Lisa called attention to the word endings explaining how adding the tion to the word consume changes it from a verb to a noun. Next, she gave the students a list of words and directed them to change the words from verbs or adjectives into nouns. Words included absorb, reflect, and discover. Students completed the worksheet in pairs and turned in their assignment.

Lisa's lesson demonstrates her struggle with introducing the concept of abstraction to her students. She could have discussed the function of the word consumption when she did her lesson, but did not which shows her lack of understanding the role of nominalization in the development of text and logical reasoning. Her explanation of abstraction was focused on how the word changes to a noun versus how the word contributes to the overall meaning of a passage. Because she uses the words in isolation, it is not clear why scientists would use this technique of abstraction. The teacher needs to demonstrate to the students why the exercise is being conducted in conjunction with an explanation of abstraction in order to further develop the students understanding of how the abstract nouns contribute to the overall meaning of a text.

When Lisa discussed why she chose to use a list of words instead of trying one of the strategies presented in class, she explained that she started with a list because she felt it might not be as overwhelming to the students as trying to reword an entire sentence. Lisa seemed to want to find a way to simplify the task for her students into a worksheet activity. In her next lesson, Lisa did move to using the sentence completion exercise presented in the professional development session. However, she had difficulty choosing appropriate words for the lesson. The example below shows how the words she chose to delete were technical words and therefore the students had to think to come up with the right answer instead of trying to insert an abstract noun that summarizes the portion of the text prior.

> In clear water some species of red algae live as deep as 200 meters. This is because phycoerythrins can absorb [red and purple wavelengths] which penetrates farther than any other color in the spectrum.

Despite Lisa's willingness to use abstraction strategies into her classroom, she struggled to successfully implement the sentence completion exercise. Her focus in the first lesson on how to change the words did not address why abstraction in science language contributed to the development of theories and ideas in science. Teaching the words in isolation did not give the students an opportunity to use the words in context and see how the abstraction functioned in the reading passage. In her next lesson, Lisa did move to using word in context, however, she chose technical word versus abstract nouns, yielding more of a vocabulary lesson instead of a lesson on language usage in science.

Two other teachers also used the sentence completion exercise to teach abstraction to their students. The purpose of a sentence completion exercise is for students to develop an understanding that an abstract noun enables scientists to summarize several ideas presented prior to the insertion of the abstract noun so that more can be said about the noun. For example, the word *achievement* in the following passage illustrates how abstract nouns synthesize the information stated previously in the text.

> At the beginning of this century the Human Genome Project made another great leap forward by completing the enormous task of reading the letters that make up the instructions in our DNA. This achievement marks the start of a process that one day will allow humans to understand completely how DNA makes us all human beings but also make us unique as individuals. (Walker, Genes & DNA, 2003, p.25)

Mona created a sentence completion lesson; however, she also had difficulty choosing the appropriate words to delete. The lesson that Mona developed reflected a typical close activity. She deleted words from sentences in the textbook and then asked students to read and complete the sentence with the word that they felt fit best. Mona used the sentence completion activity in a traditional format deleting technical vocabulary words instead of abstract nouns. The following sentences are examples of the sentences she presented to students.

- Two or more substances combine to form a single product in [synthesis] reactions.
- One substances breaks down into two or more substances in [decomposition] reactions.
- When one element displaces another in a compound, a [single-displacement] reaction occurs.

Mona directed her students to the review the first sentence on the overhead and read it aloud. “OK- this is a new reading tool called sentence completion. What word do you think goes in the blank?" Her directions do not include any information about how the language in science functions to help writer's develop ideas. In order for students to complete the exercises they must have enough prior knowledge about the topic. Students struggled with filling in the appropriate word. One student asked Mona, "What do we write in the blanks?" Another asked, "What are we supposed to write for the third one?" It appeared that the students were focused on getting the "right" word in the blanks and not thinking about the language of the sentences. (12/01/08)

When I asked Mona how she felt her students performed on the lesson, she shared with me that the students were reluctant to try and figure out the words without consulting their textbooks for the right answer. She explained that she found it challenging to encourage students to generate their own understanding of the idea that might fit into the blank because they knew she was also looking for a certain word.

> I did the sentence completion with them and I think that wasn't real clear when I did it initially. Until we went over it again and then I was like 'Okay, the biggest thing for me is they have to have the right answer, but that doesn't mean it has to be the right answer.' (IM-BM-12/01)

Mona tried to apply the ideas we discussed in class by being flexible with how students analyzed and broke down the word. However, because she chose technical words instead of abstract nouns, it was difficult to be flexible because there was a "right" answer to fill in the blank. When I asked Mona how she chose her words she said she was looking for words that were abstract. Again, this is evidence of the trend that teachers were associating abstraction in science with concepts versus with language.

During our informal meeting, I reviewed the examples from our professional development meeting about abstraction. I reiterated how this exercise was different from traditional fill-in-the-blank activities. Mona expressed concern that her students “got the important information” that she needed them to understand for the class. I encouraged her to think about how this was an exercise to train students in how to read science so they could obtain the information independently from the science texts.

Casey also attempted to use a sentence completion exercise with her students. . She took a section of the textbook and pulled a key concept she wanted students to review. She presented students with the following passage about nerve impulse transmission. The words in italics were deleted when she presented it to students.

> The plasma membrane of a resting neuron is polarized which means that there are fewer positively charged ions sitting on the inner face of the neuron’s plasma membrane than there are on its outer surface. The major positive ions inside the neuron are potassium (K+), whereas the major positive ions outside the cell are sodium (Na+).
>
> Many types of stimuli excite neurons and result in the *generation* of an electrical impulse. *This stimulation* causes “gates” or sodium channels in the cell membrane to open and positively charged sodium ions to rush in the cell resulting in a state known as depolarization.

In an informal interview after the class, Casey explained that she was looking specifically for words that might be easy for the students to put into their own words. She had hoped students could take a word like *generation* and substitute more familiar words like *to make or to create.* She *n*oticed, however, that students were reluctant to come up with their own words. Casey shared, “I think they’re just used to just copying something like this and not really understanding it. So the students are just like, ‘We can’t change these words. These are good words.’” (MT-MC-2)

Casey described her students’ response to the lesson as reluctant. During her lesson debrief, I probed more into how her students responded to the lesson. It seemed Casey was lacking the background knowledge about abstraction to provide her students with the right kind of prompts to think about abstraction. In addition, the reaction of her students influenced her confidence in addressing abstraction in her classroom.

> **Casey:** Some of them said, '*creation'* which I thought was good.
>
> **Facilitator** *:*Okay. So that was a start.
>
> **Casey:** But, I had to work to get it out of them. Then, one young man said *this* – and I said, "Actually *this* isn't too bad. It's a little vague" you know because I didn't know if he was referring to *this* or to *this*, [she points to different parts of the passage] but, the word *this* could be used at that point in the sentence and make sense.
>
> **Facilitator:** So it must have made them [the students] think about the language choices. I mean they were thinking about what that word might be. And in order to do that they had to read the previous text. The key, I think, when you're teaching them the strategy is that they can use the words around the deletion to kind of get to that word because the word before the deletion actually summarizes the deletion in this case- *stimulation* synthesizes the whole idea of these neurons creating this electrical impulse, right? So when the kid said *this* he did show that he knew the previous sentence was important in understanding the deletion. *This*, though vague, could summarize the idea.
>
> **Casey:** Okay. Do you think the words I picked were good choices?
>
> **Facilitator:** Sure, it's important though to know the function of a word, and that's why this whole idea comes, is borne out of what's called functional linguistics because they're looking at the function of words in writing and reading. Like looking at the function of stimulation- once they [the students] get the meaning then you have to draw them to looking at what that word does in the sentence. (MT-MC-4)

This conversation demonstrated Casey's difficulty in presenting the concept of abstraction to her students. In this case, she focused on asking the students to come up with homonyms for the words instead of showing them how to deconstruct the word into a verb to understand the concept. The purpose is not to change the word, but to detect the verb or adjective from which the word is derived and then move to identify what processes are part of that abstract noun.

For example, in the excerpt she used for her lesson, the focus of the discussion in class should have been on the second deletion *this stimulation*. That abstract noun, *stimulation*, encompasses the idea that the many stimuli that excite neurons make an electrical impulse. The word *stimulation* is derived from *to stimulate*, but that is just the first step in understanding what the abstract noun *stimulation* represents in this text. The next step, identifying the processes covered in the new word, is what leads students to understanding how scientists use this process of nominalization to synthesize language and build theories. Casey missed that second step in this lesson.

Patsy also demonstrated difficulty in using the sentence completion exercise. Even though the word she chose was an abstract noun, the deletion occurred at the beginning of the passage and required the students to use their prior knowledge to detect the correct word. The word she chose to delete was *mass extinction* and the explanation of the term was included after the word was introduced. This was more of an exercise in technicality than abstraction.

> Several times in Earth' history, however, [mass extinction] wiped out entire ecosystems. Food webs collapsed, and this disrupted energy flow through the biosphere. During these events, some biologists propose, many species became extinct because their environment was collapsing around them, rather than because they were unable to compete. Under these environmental pressures, *extinction* is not necessarily related to ordinary selection.

After the students correctly identified the missing word, Bette did lead them in a conversation about how the word *mass extinction* was abstract because it summarized several smaller ideas. The following dialogue occurred:

Patsy: What does this word mass extinction mean?

Student A: wiped out entire ecosystems

Patsy: How do you know that?

> **Student B:** Because it uses those words in the paragraph to explain what it means.
>
> **Patsy:** Can you put that word mass extinction into your own words?
>
> **Student C:** Yea- destroyed everything in an environment (11/19/08)

Again, Patsy did choose a word that was an abstract noun. However, her lesson focused more on getting the students to define the word *mass extinction*. Instead of choosing to talk about how the word *mass extinction* allowed the author to talk about the idea that entire ecosystems were wiped out, she focused on defining the word. Her lesson did not actually address the concept of abstraction and how to unpack it.

After Patsy's lesson, she indicated that she struggled to know the "right words" to delete. During an informal meeting, we read together through a text that she was going to use in an upcoming class to help her in identifying when an author was using abstraction to build ideas in the writing. This exercise proved to be useful to Patsy. After the meeting she expressed a more clear understanding of how abstraction worked.

> Well I know when you were reading through the wildcat article with me we were looking at it and you said, 'This is an abstraction because of where they placed it in the paragraph- it synthesize what is before it.' So that was something that was new to me. So I think that was very helpful as far as getting abstraction because that was abstract to me too. (FI-PB-6)

In the four cases above, each teacher struggled in their attempts to deliver lessons on abstraction to their classes. In the first example, Lisa pulled the words out of context, making it difficult for students to see how abstraction played a role in developing argument in texts. Then, both Lisa and Mona developed sentence completion exercises that deleted technical words instead of abstract nouns, missing the purpose of the sentence deletion exercise. Now, while Casey's and Patsy's attempts were more closely connected to the purpose of a sentence completion lesson, the discussion with students' did not lead them to thinking about the purpose of the abstract noun in the passage. Both were concerned with getting students to rename the word to connect with prior knowledge or define the word appropriately. The class discussion was not effective in pushing students towards understanding how the word functioned in the science text.

One teacher, Bette, demonstrated a better understanding of how abstraction was used in science writing. Instead of asking students to participate in an exercise like sentence completion, this teacher felt that modeling through think alouds was more appropriate for her students. She did not ask students to independently apply the technique of abstraction; she used it more as a teaching tool.

Bette's lesson more closely reflected the ideas we discussed in our professional development session. Her biology class was studying the concept of population growth. She opened by reading the following passage from her text.

> Sea otters are important members of the kelp forest community of America's Pacific Northwest coast. This "forest" is made up of algae called giant kelp, with stalks up to 30 meters long, and smaller types of kelp. The kelp forest provides a habitat for a variety of animals. Sea otters need a lot of energy to stay warm in the cold water, so they eat large quantities of their favorite food: sea urchins. Sea urchins, in turn feed on kelp. *The relationships* along this food chain set the stage for a classic tale of population growth and decline. A century ago, otter were nearly eliminated by hunters.

In this passage, the word *relationships* allowed the writer to summarize the ideas introduced in the first paragraph. The next section of the text then continues to elaborate on the relationships impact on population growth and decline. Bette called her students attention to the word *relationships*. She asked the students to explain what the author was referring to when he used the word. Students were able to explain that the author was talking about the chain between the sea otters, the sea urchins, and the kelp.

In her discussion, Bette explained how scientists use this idea of abstraction to help develop ideas in their writing. She clearly showed how relationships summarized the ideas previously presented in the text. When asked about her lesson, Bette felt that introducing the idea by showing the students example in their reading was enough for her students to understand it. Bette explained that when she sees an abstract word in a sentence, she asks students to explain what it means.

> Now when I come across a word like the *concept* or *significance*, I try to have the students go back and figure out what they are talking about; what is the *significance* or what's the *concept*, what does that mean? Then I can really kind of focus on their understanding at that level. (MT-JB-8)

Even though the teachers struggled with successful integration of the concept of abstraction, they were thinking more deeply about the ideas as evidenced by our conversations during professional development sessions. Several teachers expressed that they believed it was important to talk about the idea of abstraction in their classrooms. Brad shared in a professional development session how he talked about abstraction with his students. Brad commented,

> You know when they [authors] say *cutting down trees* and *deforestation*, they mean the same thing. Now I notice that and I can call it to students' attention when we are reading. I can ask them how they can say a word like *deforestation* or *journey* in another way. (PD5-12/09/08)

In an email communication, Lisa further noted that she believes she needs to address the concept of abstraction in her teaching.

> When I hit an abstract word I need to take the time to explain it, break it down into its components, and reduce it into manageable bites for the students to consume. Once I do some modeling on how to do this sort of process, it will get easier for them. (EC-VL-11/10/08)

In summary, the science teachers showed a willingness to integrate the concept of abstraction in science language into their instructional routines. However, several of the teachers struggled to show their students how the idea of abstraction was used by writers of science to help build ideas and theories. The teachers' prior experiences with vocabulary lessons drew their attention to the technicality of the language versus the abstraction and the focus of the lessons was often on word level analysis instead of addressing the abstract language in context. Instead of showing the students how a word was used to synthesize the previous ideas before it, the teachers focused more on the technicality of science language, showing concern for students to know particular vocabulary. In addition, the limited resources for reading in the classroom influenced the variety of materials available for the teachers to find examples of abstraction and provide a wide reading experience for the students.

Density

The science teachers struggled with the integration of density exercises into their teaching routines. Two themes were prevalent in the data when teachers attempted integration of lessons about the density of science language. First, it was difficult for teachers to find examples of long, complex nouns in their textbooks. Second, because it was difficult to find long, complex nouns, the science teachers relied on support through assistance in planning and demonstration lessons in order to execute the lessons on density.

The science teachers were concerned with finding sample passages with long, complex nouns from the textbooks. As demonstrated in a previous example, Billie felt that many of the sentences in her textbook were simplified. She and I met to look at some sample passages, and she determined that she wanted to use another textbook to look for better examples of sentences with long, complex nouns. Mona had a similar feeling about some of the information in her physical science textbook. She stated that much of the information was presented to the students in a simplified manner. She read the following sentence from her textbook to me during an informal meeting:

> How many different ways have you used energy today? Today, Coral and Buster used a hair dryer or a toaster. If you did, you used energy. Furnaces and stoves use thermal energy to heat buildings and cook. (IM-BM-FN- 01/21)

Mona was concerned that the textbook writers do not use enough "real" science writing in their attempts to make it easier for students to understand. She commented that the density of the passage she read was typical for the reading that was offered in many sections of her textbook. Because Mona did not feel that her textbook contained enough examples of density in science language, I encouraged her to think about ways that she could bring samples into the classroom.

> **Mona:** So what I'm going to try to do is pull articles; and I may actually go to Jennifer and ask for some articles or bits out of her book just to copy and give to my kids; because I'm not getting them ready out of our book. That's an injustice to them. When they go to honor's chemistry next year, it will be even worse. So I want to pull – in fact I just thought of that; and that's a wonderful idea.
>
> **Facilitator:** Yeah that's a good idea.
>
> **Mona:** Get like paragraphs from the honor's bio and chem.
>
> **Facilitator:** That's a great idea. Get them exposed to the density and show them how to analyze the more complex passages. (IM- BM-01-21)

One solution for the teachers who perceived that their textbooks did not have enough examples was to locate alternative sources for reading material. Because Mona and Billie both taught the same physical science course, they agreed to work together to find some examples to supplement their textbooks.

Brad also contacted me for assistance in planning his lesson. During our meeting, he perused several paragraphs of the text about arthropods noting that most of the nouns used at the beginning of the sentences were simple. He pointed to a paragraph in the text as an example.

Arthropods are generally *quick, active animals*. They crawl, run, climb, dig, swim, and fly. As you would expect, arthropods have *efficient respiratory structures that ensure rapid oxygen delivery to cells*. *This large oxygen demand* is needed to sustain *the high levels of metabolism required for rapid movements* (Biggs, et al., 2006, p. 744).

Even though the nouns in the subject position were mostly simple [e.g arthropods, you, they), the passage included long, complex nouns. However, because they were placed at the end of the sentence, Brad did not notice them when he was reading. From our study of density, he had picked up on the complication of the long, complex nouns serving in the subject position. He understood that this was the main challenge to students because students were used to everyday language where subjects of the sentences were simple like *he* or *I*.

In the next step of our meeting, he requested assistance in conducting his lesson. We found a sentence in his text to use as an example and decided to begin with simply identifying the long, complex nouns for the students. Brad thought that it would be easier to use a sentence with the complex noun in the subject position. He thought it would be easier to relate to the students' knowledge of everyday language in order to compare the long noun to a simple noun. In science writing, the lengthy complex nouns often serve to define a concept. Because Brad was concerned with connecting the idea of density to his students' experience with reading, I encouraged Brad to start with a sentence that explained a definition. The following sentence was selected.

Light waves that have their electric fields vibrating in the same direction are said to be polarized (*Biggs et al, 2006, p.744).*

We taught the lesson together. To open the lesson, we talked about how scientists expand nouns to pack much information into sentences and compared a simple subject from a narrative text to the complex noun that served in the subject role in a sample science text. Brad reminded the students that often the technical words or concepts that they learn about are defined in the text, and he asked if students sometimes had difficulty understanding the definition when they read it in their textbooks. A number of hands were raised.

Next, we displayed the model sentence Brad had chosen and asked students to think about what the author of the text was trying to tell us. Once it was established that the sentence was defining polarization, we began to deconstruct the long, complex noun. I explained to the students how the head noun in the sentence was *waves* and then asked students what else they noticed about waves from the other words in the sentence. One student said that the waves were *light waves* explaining what kind of waves. Students were also able to identify that there was a prepositional phrase *in the same direction*. Students noticed the information about the electric fields but did not know how to label that part of the sentence. I addressed how it is important to look at all parts of the sentence because the information is an important part of understanding the definition. For example, *that have their electric fields vibrating is* a postmodfier answering which waves? Brad continued explaining that scientists use these long complex nouns to write about science topics. He then directed the students to look at two sentences on the overhead. He explained the process of sentence combining and then asked the students to create a long, complex noun by writing one sentence.

Quick movements enable arthropods to respond to a variety of stimuli.

These quick movements are the result of strong muscular contractions.

I then explained how combining sentences can help writers develop sentences that sound more like science language. If scientists used short, choppy sentences it would take too long to tell the reader about the ideas. Students practiced with a partner and then shared examples. We used the following example to show the students how the long, complex noun served to pack the information from the previous two sentences.

Quick movements *that are the result of strong muscular contractions* enable arthropods to respond to *a variety of stimuli*.

Brad pointed out to students that the head noun was *movements* then I explained how the adjective *quick* modified movements and then the embedded clause *that are the result of strong muscular contractions* gives more details about the noun. I also pointed out that another complex noun appeared in the sentence *a variety of stimuli* (01/27/09).

Brad struggled with identifying the long, complex nouns in his textbook. Part of the reason was because he was expecting the long, complex noun to appear in the beginning of the sentence. After our informal meetings, he did try another lesson on his own in which he asked the students to put the information from the long complex nouns into their own words. He read the following sentence from the textbook and then modeled putting it into his own words. After that, he did another sentence and asked the students to write the information in their own words.

> Textbook sample: Fertilization occurs when a sperm cell penetrates the egg cell, forming a new cell called a zygote.

> Brad's sample: A sperm cell must break through an egg cell in order to fertilize it. When a sperm cell does this the new cell is called a zygote

Brad reported that he tried several more lessons on his own, but he did not feel it was making an impact on his students.

> I was like, all right, and then I did a couple lessons and Carla [student teacher] did a couple. And they're just - they're fine. They didn't all do it. It's just like too hard because they won't read. It still goes back to the I'm not going to read; I'm 15 and I know everything" (PD-03-15)

In another example, Bette requested support in planning her density lesson. As she planned for a lesson about osmosis, she found several passage that contained complex nouns. For example, she noted this sentence about facilitated diffusion from her textbook during our meeting, and we talked about where the long nouns were located.

> Therefore, a net movement of molecules across a cell membrane will occur only if there is a higher concentration of the particular molecules on one side than on the other side. (Miller & Levine, 2006, p.185)

In this passage, there are two prepositional phrases *of molecules* and *across a cell membrane* modifying the head noun *a net movement*. Then there is the complex noun *a higher concentration* (head noun) *of the particular molecules* (prepositional phrase) *on one side than* (prepositional phrase) *on the other side* (prepositional phrase).

While Bette felt that she could identify longer, complex nouns in her advanced textbook, she was still concerned about how to discuss the grammatical features with her students. She requested that I come in and do a model exercise for her for this lesson. I conducted a brief lesson with her students using the chapter on osmosis. The lesson opened with modeling the following sentence on the overhead (1/27/09).

> *During facilitated diffusion, molecules, such as glucose, that cannot diffuse across the cell membrane's lipid bilayer on their own / move through protein channels instead. (Miller & Levine, 2006, p. 187)*

After a brief discussion of the complexity of this sentence we analyzed why it was complex by breaking it down into pre-modifiers/head noun/post modifiers. Table 6.1 shows the material that was presented to the students.

After the lesson, Bette designed her own lesson using a sentence from her college textbook to demonstrate to students that this phenomenon of density on science language was going to be even more of a challenge in college. She addressed how the writers expanded the nouns to add information, yet showed the students that the topic was just a more elaborate explanation of what they already knew from their own reading in their textbook.

We designed another lesson together about osmosis the next week. During our informal meetings I had emphasized that the ultimate goal was for students to be able to not only detect the long, complex nouns but to put the information into their own words to improve student understanding. The lesson opened with reading the first two paragraphs about osmosis. We read the opening paragraph out loud to students and Bette modeled how to think out loud about the long, complex nouns. She started by identifying them in her reading. The she showed how she put the ideas into her own words, writing out her thoughts on the overhead as she talked. Following is the sample she used.

> Although many substances can diffuse across biological membranes, some are too large or too strongly charged to cross the lipid bilayer. If a substance is able to diffuse across a membrane, the membrane is said to

> be permeable to it. A membrane is impermeable to substances that cannot pass across it. Most biological membranes are selectively permeable, meaning that some substances can pass across them and others cannot. (Miller & Levine, 2006, p.185).
>
> Bette's words:
>
> Some substances move through the edges of the cells and some cannot cross the lipid bilayer because they are too big or charged too much to get through. Sometimes stuff can move through the border of a cell. This means that the membrane of that cell is permeable which means that a substance can break up and move through the edges of that cell. Sometimes stuff cannot move though the border though. When this happens, the cell membrane is called impermeable because nothing can move though it. It is important to know though that most biological membranes are in between permeable and not permeable. Some things can pass through and some things cannot pass through. This is called selectively permeable.

Bette tried to simplify her language while she modeled how to think aloud about the passage. She spent time talking through each sentence and its parts as she wrote her ideas on the overhead. When she was done, I explained to the students that we were going to ask them to write their own interpretations on the next part.

> Water passes quite easily across most membranes, even though many solute molecules cannot. An important process known as osmosis is the result. Osmosis is the diffusion of water through a selectively permeable membrane. (Miller & Levine, 2006, p. 187)

Bette directed the students to look closely at the final sentence that defined osmosis and try to put that long, complex noun into their own words. The following student samples illustrate the results of asking the students to put the information from the long, complex nouns into their own words.

- Sample 1: Osmosis is when water molecules can get through a membrane that allows only some stuff to pass through it. Water uses osmosis to get through past the protective layer of the cell membrane.
- Sample 2: Osmosis is when water goes through something when other things don't.

- Sample 3: It is easy for water to get through most membrane even when other liquids cannot get through. When that happen it is called osmosis. Osmosis is the of water through a membrane that some things pass through and others do not.

Despite Bette's willingness for me to come into the classroom and model a lesson, she still did not feel confident using the lessons on density in science language in her classroom on her own. In our final interview, Bette addressed her concerns about teaching density lessons in her classroom.

> I mean, I know what it is, and again, for me, you know, when you taught it, I was, like, oh, that sounds easy. I get what she was saying. But to get the kids on page with that one, again, they struggled with that one and it was hard, you know? And maybe it was cause I didn't have the ability to teach it well enough. You know, like, taking it – what I know and applying it in the teacher setting. So I don't know if it was just I didn't do it enough or that sort of thing. So I think, again, building it in next year and doing it more might be a better way to see if they get a better understanding of it and whatnot. (FI-JB-6)

Casey also did a sentence combining exercise with her students. She identified a sentence from her textbook that contained a long, complex noun. She then broke the sentence into three individual sentences and asked the students to combine the ideas into one sentence.

- Endocrine glands release chemicals called hormones.
- Hormones travel through the bloodstream.
- Hormones bind with receptor molecules.

Casey explained to her students that they were doing this because science reading can be difficult, and if a reader can begin to break ideas down and put the ideas back together, then they will be able to better understand what they are reading. Students were easily able to combine the sentences to make the writing more complex. The following two examples illustrate sentences put together by students:

- Student A: Endocrine glands release chemicals called hormones which travel through the bloodstream and bind with the receptor molecules.

- Student B: Endocrine glands release chemicals that travel through the bloodstream and bind with receptor molecules called hormones.

After Casey's lesson she expressed that she was impressed that students could combine the sentences and make it sound more scientific. She did recognize that the second example did actually not add clarity to the information. The problem with the second sentence was that the student did know that hormones are chemicals. The sentence reads as if the receptor molecules are the hormones. In the following case, *hormones* become the head noun and *that travel through the bloodstream and bind with the receptor molecules when they are released by the endocrine glands* is the post-modifier.

Hormones are chemicals that travel through the bloodstream and bind with the receptor molecules when they are released by the endocrine glands.

Casey revisited her textbook and tried the lesson again. This time, she looked for a segment of text that would put the students in a better position to have to develop a long, complex noun. The following sentences were presented to the students:

- Elevation of blood sugar by promoting synthesis of glucose from amino acids is known as Gluconeogenisis.
- Gluconeogenisis encourages the use of fats by fuels.
- Sparing glucose is an effect of growth hormone.

Casey reported that she was pleased that the students were engaged in the lesson and believed that when they were engaged in the process of combing the sentences it was also supporting their learning of the concepts she wanted them to know.

Both Brad and Casey had a similar experience when introducing the strategy of sentence combining to their students. Several students who were part of the intensive reading class told them that they had used the strategy and were familiar with combining sentences. The purpose of sentence combining in language arts is often to develop more complex sentences. While the emphasis is not necessarily on developing more complex nouns, the strategy is similar. In this case, it provided these students with a good fame of reference for performing the task. Brad reported that it was useful that the idea was familiar to some students because that helped with student participation. He commented in his reflection on the lesson,

> I was surprised when we introduced the idea and Brandy piped up that she had done this already in her reading class. Then she really seemed to get it with the science material. I was impressed. (PD-02-45)

Billie also felt challenged in planning her lesson. Prior to her lesson, we looked through her textbook together to find samples. She thought it would be useful for her students to recognize how science writing can have a long noun group in the same place as a subject of a more typical sentence from a fiction novel. She wanted to capitalize on showing her students how the two types of writing were at the same time, similar and different. Billie opened her lesson by showing her students simple sentences from a novel and asking them to identify the subject and verb. (e.g. *Lou sat down on a packing case. He rubbed a small red sore on the top of his bald head*. From *The Contender* by Robert Lipsyte). Next, she introduced a science sentence and asked them to identify the subject. She used the following sentence:

The kinds of electric forces that hold atoms together also bring atoms together to form compounds. (*Reading Essentials, p.389*)

During her observation, Billie discussed with the students how the science writing was still set up like a novel, but the nouns were longer (e.g., The kinds of electric forces that hold atoms together) She mentioned issues like “this can make it harder for you to understand” and “this is how scientists like to write” trying to emphasize to her students that it was the actual language that was challenging. She also talked through what the words meant in the long noun phrase asking students questions like, “Now which kind of electric forces is the author talking about?” After the lesson, Billie reflected on her students’ participation. She said,

> I think with the ninth graders it is tough to recognize the whole subject because they are used to that novel reading where it’s Dan, Joe, the dog. And it’s real short. And part of this lengthy process is that in science they make it longer in their writing, so I think that this is good to do with them and see if they start recognizing it on their own. If they can see that the whole thing is a subject. (IM-JTB-11)

Patsy also requested a meeting prior to her lesson to discuss how to implement the lesson on density. She used a supplemental article about Cheetahs for her lesson on density. Prior to the lesson, Patsy and I analyzed the passage, searching for examples of long, complex nouns. She chose the following paragraph from the text to show students how a long, complex noun contributed to the density of science language. She pulled the paragraph from the text and posted it on the overhead with the long, complex nouns italicized.

> When there is a normal variation of alleles in the gene pool, one would expect rejection of grafts between unrelated cheetahs after 7 to 13 days. The nonrejection of these grafts supported the hypothesis that the population bottleneck reduced the allelic variation in the gene pool of the cheetah. The rejection of the grafts from the domestic cat indicated that the immune system was responsive to genetically different transplanted tissues (Biological Science: An Ecological Approach, 1987, p. 295).

During the lesson, Patsy worked with students to identify the parts of the complex noun groups. As she identified the long, complex nouns she addressed how it was important to be aware of how scientists write and how they put words together so the students could start to break it apart and understand it. As she was working through it, she talked about the passage in her own words also showing the students how to put it into their own words. She was not comfortable with the material, however. Twice during the lesson, she consulted with me asking, "Is this the right way to explain this?" After she delivered the lesson, however, Patsy felt that it was a good strategy to get students to identify the long, complex nouns in the sentences and put it into their own words.

> Having them like we did in that class that day Connection in our talking was to look at what does this part mean, okay or leave that part out and just look at where is the meat of this sentence and let's just look at that. And now that we've got that down let's just add this little piece and let's add this little piece to break it down into smaller chunks that they can understand for comprehension. I think was a good technique. (MI-PB-6)

In the professional development meeting after this set of lessons was delivered, the teachers still expressed concern about why we would conduct a lesson like a sentence combining activity. I explained how sentence combining encourages students to connect their everyday language to science language. We reviewed a sentence combining model lesson. The two sentences standing alone have simple nouns *a tornado* and *it* and sound more like the every day language of students. The information following those two nouns can be combined to create a longer more complex sentence.

- A tornado is a column of air.
- It reaches from the clouds to the ground, and it rotates violently.

In our discussion of this strategy I explained to the teachers how the sentence combining involves giving the kids two ideas and getting them to work on combining those to think about writing a little bit more like a scientist. In this set of sentences, there are three pieces of information about tornadoes: (a) It's a column of air, (b) It reaches from the clouds to the ground, and (c) It rotates violently. Blending the sentences creates a sentence that sounds more like science language.

A tornado is a violently rotating column of air that reaches from the clouds to the ground.

In response to our review of sentence combining and density, Lisa asked why we would want students to combine the sentences. The following excerpt from the transcript of that session demonstrates her struggle with understanding why it is important for students to practice sentence combining.

> **Lisa:** I have a question. I understand that everything that's going on there. Why are we - it seems to me that's making it more dense.
>
> ***Facilitator:*** Yes.
>
> **Lisa:** So that's okay. That falls under density? It's just kind of increasing -
>
> **Facilitator:** It is improving their writing- what this is doing is it's allowing students to learn to write like a scientist, so that they are comfortable kind of starting to move them to be able to write at a different level. And also read more complex sentences and be able to see the different parts.
>
> ***Bette:*** Right.
>
> **Patsy:** And that's what we tend to see in a lot of their writing like they're writing science reports. A lot of those short sentences, I did in my science project reports.
>
> **Facilitator:** Right. Students sometimes don't combine the sentences, and we want them to begin to write more elaborately. We want them to begin to write more efficiently, and if they're going to do that especially when they move into different levels of science. Then they need to be able to - because what we're going trying to do through these exercises is to embrace the way that science works. You know one of the first things I think if you remember we talked about is we don't always want to make it easier to read because science is science for a reason, and it is a appropriate sometimes to break it down, but it's also appropriate that they can build it back -
>
> **Patsy:** Together.
>
> **Facilitator:** Up and put it back together. And so the sentence combining strategy - and you can do these sentence combined strategies in both directions. You can give them the dense sentence and try to have them break it down to the ideas, but the overall goal here is that students begin to see how to manipulate the words to write and read science more effectively

and see the connections between their own words and the science language.

Lisa: That makes more sense to me now. (PD- 02-09)

In summary, the science teachers struggled with integrating strategies into their teaching that addressed how science language was dense. Like abstraction, the unfamiliarity of the information contributed to teachers' hesitation to implement the ideas into their classroom. The science teachers lacked basic knowledge of grammar and its role in science, and therefore viewed addressing grammatical structures such as embedded clauses as an "English thing." In addition, the resources the teachers were using were limited to their textbooks and the teachers struggled in locating examples of sentences that contained long complex nouns. Finally, the issue of time was a factor because the science teachers needed a greater amount of support and feedback about their implementation of lessons on density in science language and it was challenging to find enough time to provided the appropriate amount of support in planning and feedback on the lessons.

Genre

The science teachers in the study integrated the concept of genres into their lessons in various ways. During the professional development session, the teachers were introduced to the genre teaching cycle. In this cycle, teachers begin with the preparation phase in which they select appropriate and related readings to their curriculum and immerse their students in a variety of genres. In the next phase, teachers introduce a text model of the target genre and engage students in an explicit discussion of the genre in terms of its social purpose, text structure, and grammatical features. The third phase involves engaging students in the actual writing of particular genres through joint construction with peers or the class. The final phase is independent construction; students should be able to write successfully in the genre independently.

During the planning part of the professional development session, the teachers talked extensively about how to introduce these ideas to students and implement the iterative genre teaching cycle. Mona commented about the preparation phase of the cycle:

> As I was reading through this page 27, just the whole preparation part where it says collect sample, I think that's huge. That's where, as a teacher, I need to kind of really work on that is collecting samples, just being proactive and looking outside of my textbook to go to the internet and articles and stuff like that, you know, to really pull some examples. (PD-2/10/09)

Time was a constant theme throughout the discussion on how to implement the genre teaching cycle. The teachers expressed concern over the length of time it would take to follow the entire cycle. Brad commented that this was an idea he would use in his planning next year, but he thought it was difficult to think about using for a single lesson (FN-2/17/09). Patsy commented that she was thinking about her own expectations of students.

> As a teacher is I realize that so many times, especially with the honors kids and especially as an adult having already gone through high school, college, I just expect my students to already be at number four, to be at independent construction. (PD-2/10/09)

When discussing implementation of the iterative genre teaching cycle, the teachers expressed concern about the amount of time it would take to model all of the various genres. The following transcript excerpt demonstrates the teachers' thinking about the use of modeling in teaching about genres in science.

Billie: And I don't know, it's just a – I don't know, I think it's something that, especially with new teachers, it's something that you can't just – any teacher really that doesn't get it, I think that's a huge part is like this whole modeling thing. I got to get better about that. You know, that's something I'm just poor at.

Facilitator: I think when you take the time to teach the *how*, eventually, they learn more. But what it takes it building that foundation of, you know, teaching them the how and then it takes a lot longer, so you may feel like you're not getting as far in the curriculum and then all of a sudden though, once they start to get that how, then all of a sudden, phew, you know, they're writing really well.

Brad: Imagine if you started at the beginning of the year with this kind of stuff and for two weeks and just – and modeled right after every lesson. They'd be fine. They'd start to get it.

Facilitator: And again, that whole argument over the content versus the modeling and the strategy, I think when you embrace this idea of modeling and calling attention to the language and using some of these strategies that eventually the content is richer and you turn out students who – more students who can read and write better in the field of science.

Lisa: And here's the thing about this course, and back to what you were discussing with modeling, I hadn't heard of this not being a reading teacher and so getting into modeling in the classroom with the reading strategies to help them – I'm very happy with this, but I'm gonna have to stretch my muscles a good bit to work on some strategies that will work in marine science to do this kind of thing. We're doing teaching reading and we're teaching science and you can still do both, but it requires a huge greater amount of effort in one sense to go back and learn all the modeling strategies 'cause we're not English teachers.

Facilitator: I would argue in terms of it being an English thing, that there's no one better to teach their kids how to read science than you guys. I think there's nobody better than you people who are experts in science to teach the kids how to read and understand science. (PD-2/10/09)

Lisa commented that she modeled how to write directions at the start of each year. She conducted a lesson at the start of each year about writing clear directions with her students. She wondered if this type of lesson addressed the issues of how to write a procedure correctly.

> **Lisa:** I do the peanut butter and then I take it and use their directions to make the sandwich and it's hilarious. Because they'll say, "Take the peanut butter and put it on the bread." Now what do you want me to do? You know, they don't – they're not – and that – I do it because I want them like, especially when they're writing for science fair or something, telling me to take the peanut butter and put it on the bread is kind of vague. Yeah, anybody knows how to make a peanut butter sandwich, but that – the point is, if you don't give me specific, like take the – put the knife in, you know, I mean some, you know, those are important when you're talking about procedures. If it's not specific, it's not gonna come out real good.
>
> **Facilitator:** Right. And here's where you could put that twist on that exercise with okay, well let's look at what kind of language should you be using. What kind of words should I see in you're writing procedures? I should see some declarative sentences *take* this, *put* this and some temporal conjunctions *first, then next*. That's the kind of language that you use when you write a procedure. So that's what I mean by putting a twist on it. If you're asking the kids to do this now, you're using language to get them to think about looking at the text structure and the format and the purpose of that type of writing. And once they can start to kind of recognize those text structures, then again, they're going to get better at writing them. (PD7-2/10/09)

As these science teachers continued to share ideas about how to teach students about genres in science texts, I continued to prompt them to think about how language played a role in the development of these text structures. Phase 3 of the iterative cycle which involves modeling the writing of the targeted genre was a concern for teachers due to the amount of time it would take to engage students in this part of the cycle.

Even though they were concerned about the time, they tried to think of ways they could bring the strategies into their classroom, if not immediately, then in later lessons. For example, Brad shared his plans for using genres in his classroom the following year. Learning about genres had raised his awareness about the genres his students were familiar with and the ones they needed more attendance to learning. In our final professional development meeting, Brad shared his idea with the teachers:

> One thing I pulled out of this was the first four they [students] pretty much – they see procedure, they see a recount, they see report and they see

> explanation all the time in the writing, but they're not too familiar with how to see exposition and discussion. When we were going over everything, they'll do something on endangered species and I do a genetic disorder, but it's just writing a bunch of information down and giving it to me. I was like what I'm going to do next year is like should the gray wolf be released? Is it a good thing that's in back in the area or do you agree with the forum? Pick a side and write me a paper that way. This way you're forced to write an exposition paper. (PD8-3/10-13)

Further, teachers struggled to bring the ideas from the iterative genre teaching cycle into their daily plans. The concept of a teaching cycle implies a process that becomes a part of the teaching in a particular classroom. The science teachers bantered about how to begin the process. One concern raised was whether to introduce one genre at a time or all of the genres at once. Casey shared her insight:

> The first, you know, as we were thinking about this, my first thought was procedures, so I can give the students even examples in the book. This is the subject. Now how are we gonna study it. And I have done that already a couple of times this year, so this would not be new, but the business about discussion, exposition, you know, all that, that would be a little bit new. But procedures wouldn't be, so I feel really comfortable with that. So we can pick just one, expose them to that and then eventually – and then have them write, get to the point of their writing it rather than exposing them to all of them? (PD7-2/10/09)

Bette responded to Casey that she felt her kids would do better to see all of the genres and to recognize them across the readings that were used in the classroom. She stated:

> I think it would be neat to do two that are related, like procedures and recounts or like exposition and discussion. I think that would be easy to – not easy, but I would, you know, somewhat easily tell my kids, "Okay you know how sometimes you know, they talk about persuasive writing, well in science exposition means this. We're giving information, but we're kind of skewing the purpose behind it one way to get you to feel this certain way about this, you know, and believe this, whereas discussion, we're gonna talk about both sides of the story," you know, what whole, you know, I think it would be better for me to do it that way with my kids. (PD7-2/10/09)

The science teachers favored the idea of the iterative teaching cycle. Even though they struggled with how to plan lessons and how to introduce the teaching cycle into their daily teaching practice, they saw value in engaging students in learning about the genres of science language. Bette summarized her feelings about integrating the iterative genre teaching cycle into her plans.

> I think that again, this teaching cycle of, you know, the immersion in the different types of genres and the attention to talking about the different, you know text structures and social purposes and then allowing them to kind of jointly and then independently construct is a powerful model. I think it would take some dedication and some thought, but I think that it's – I think there's a lot of potential there. (FI-JB-6)

Data analysis revealed two ways that teachers chose to begin the implementation process of the iterative genre teaching cycle. First, some teachers concentrated on just one genre during their instructional lesson. Second, some science teachers introduced some or all of the genres at the same time. For example, Both Casey and Lisa introduced the genre lesson with just one genre. In this case, both started with procedure because they felt that their students were most comfortable with that one. Casey chose to focus her lesson on the procedures for taking a pulse and taking blood pressure. She began by showing the students the written procedures for taking a pulse. She asked students to identify the purpose of the type of writing. "What would you call this? What is the author's purpose for writing this information?"

She then asked students to look at what kind of words the author used to achieve the purpose of giving the directions. She pointed out the declarative words like *secure, rest, and move.* Next, she called students' attention to the steps and the use of ordinal numbers in presentation of the information. After students practiced following the procedure of taking a pulse, Casey showed them a brief video on taking blood pressure.

She instructed the students to watch closely because after the video, they were going to write the directions together as a class for taking blood pressure. (3/2/09)

Lisa also worked with the genre of procedure in her genre lesson. She gave the definition of a genre and then a brief overview of each of the six categories. She then focused on a previous lab the students had completed on how to make their own oil spill. Lisa reviewed the procedures step-by-step. In reflecting on her lesson, Lisa shared with the other science teachers:

> We talked about a social purpose, the text structure, the grammatical features, imperative and declarative sentences and such. We talked about action verbs, which they knew from FCAT work we've done before. Then I showed them the full procedure for the oil spill lab and talked about how it fit into the genre of procedure. Then, I asked them to describe the correct sequence in good detail of the procedure for setting up and using a standard microscope; include the steps for focusing the slide as well. Some of the kids were so precise they even wrote, 'Walk in the door, set down your gear, and put your things up, walk over to the microscope. Carry it,' and a lot of them said, 'What's the thing under the base called?" They asked, "Are we preparing the slide?" They started using very sharp questions about the slide. "Prepare or we have to make our slide and then as the slide is prepared you have to put it on the station and focus." A couple of them said, 'The big knob what is that called?' I told them the *course adjust*. So there was also a little discussion on terminology also. (PD7-2/10/09)

Both Lisa and Casey focused on one genre to introduce the concept of genres to their students. Even though in the secondary setting, the goal is to move students to understanding how to read and write the genres of exposition and discussion, these teachers needed to start with a genre in which they had a certain comfort level. In addition, in both of these teachers' classrooms, labs were a prominent part of the curriculum, so following procedures was a familiar genre to the students also.

Two other teachers chose to introduce all six genres to their students and asked students to read from multiple sources to identify the genres. Brad began by revising the presentation I had done for the teachers. He reviewed each genre with his students and had them read an example to demonstrate how that genre was organized. Brad shared the following in a professional development session:

> My students got it. They said, "OK, to recount something is to remember, to recall, to report something you write a scientific report, it's going to have steps.' So we went over that and spent a lot of time on it. And then the third day I actually used the ones we did in here and we read them and tried to identify the correct genre. They did really well except for the same two we had a problem with. The last day I just took four or five paragraphs out of the book. I said go to page 63 and read the second paragraph- I picked the examples right from the book. By the end of the four days they thought it was easy. So it worked out pretty good. (PD8-03/10/09)

Bette introduced genre to her students in a similar way. She introduced two genres at a time, grouping procedure and recount, report and explanation, and discussion and exposition. She found relevant examples of each genre and asked her students to try and correctly identify the genre. Bette shared in the professional development session:

> I found a report on RNA. We talked about RNA and DNA. This is a *report* about RNA. They found this one pretty quickly I think. This one was *explanation* all about DNA. This is the one some of my kids, they weren't sure if it was a report or explanation. I heard them going back and forth like we were doing the last time. 'No that's a report. That's an explanation. Look how much detail goes into it.' I heard that. I was like very good! Something happened! It got them talking. I haven't heard them talking so much, but I had to say I was excited to see that they actually got it and were trying. (PD8-03/10/09)

Mona also introduced the genre teaching cycle to her students by giving them multiple samples to read. She opened by telling students "I want to prepare you to read all kinds of science." She found 25 different articles from contemporary sources like the daily newspaper or science magazines like *National Geographic*. She passed out the articles and asked students to read their article. Next, she posted the chart from the professional development session explaining the six genres on the overhead. Mona then reviewed each genre, explaining the text structure and the grammatical features of each genre.

Mona put the sample of a procedure on the overhead and asked, “Who can tell me the difference between a declarative and an imperative sentence? We need to know this. Think about what you should have learned in English class. Can you identify declarative or imperative sentences in this procedure?”

A student commented that the sentences that told the reader what to do were imperative because they were not regular sentences. He pointed to the sentences that read *cut one of index cards* and *Place the two halves of the index card over one of the holes.* Mona checked for clarity of his comment about ‘regular sentences’. She asked if ‘regular sentences’ were like “Physical properties of matter include color and texture.” When he agreed, she defined this type of sentence as a declarative sentence. Mona continued to explain each genre, showing an example of that genre and reviewing the social purpose, the text structure, and the grammatical features of that genre. (3/05/09)

In her final interview, Lisa shared her opinion about her lesson on genres. She expressed that she was beginning to sense a change in her own perceptions of how language was used in science. She was surprised when she spontaneously started to address the language features of the write-up of students’ lab reports.

> I actually sat in class the other day with my Marine Science II. They had to write up a report on a lab they did on oil pollution where they made their own oil spills. And I said when you read how to do the lab that was a procedure. Do this, do this, do this. You had these verbs, you had this procedure, and it told you what to do. What I'm asking you for you're not reiterating procedure you're doing a report. You need to tell me not just the step that was the procedural step, but what did you observe happening. When you write all this up you are writing a report. You are giving me a summary of your findings. You have your data sheets. You have your procedure sheets. You put it all together in the blender and it comes out

> the report. Do you understand the difference in the genre between procedure and report? And they got it. The lights went on. (FI-VL-3)

Billie also reflected on the teaching cycle. She decided to wait until she could collect more samples before she introduced it to her students. Billie was the only teacher who did not attempt a lesson during the research cycle. But, she had a plan.

> My plan for the next nine weeks is to work it into their current events. They are going to bring an article in and choose whatever genre it fits then explain why. So I will train them in the genres first, and then we will move to that. I'll have to do a few examples before I let them off running. You know, like, they did, put some examples up and talk about what they think this one is and that kind of thing. So some of that training, per se, beforehand, but I think that one for the kids won't be that hard, because they do already do some of it. You know, they see procedures. They – you know, oh, that's a report. Well, they may not know it's called that, but now they'll start to see that even within one there could be different genres that are there. (FI-JTB-5)

The science teachers attempted to integrate the idea of genres in science reading in their classrooms in various ways. These science teachers either introduced a single genre to the students or reviewed all six genres with their students. However, time was a factor in the teachers' integration of the genre teaching cycle into their teaching. The teachers indicted more time would allow them to collect more samples of different genres and plan for how to use them to teach the genres. In addition, the teachers' lack of grammar knowledge further inhibited their level of confidence in talking about the grammatical features of each genre with their students. Lessons focused more on differences in purpose and structures of the language versus grammatical features. Overall, the science teachers supported the use of the genre teaching cycle in teaching about text structure in science language despite their concern with the implementation process.

The science teachers demonstrated an emerging understanding about how science language worked to develop ideas in scientific texts. The science teachers favored using strategies that addressed technicality in their classrooms. This is not surprising due to the fact that the most self-reported reason for students struggle in reading science by these science teachers was lack of vocabulary knowledge. Though teachers reported change in understanding that challenges in science texts could be attributed to more than vocabulary knowledge, technicality was the area in which the teachers had the most prior knowledge and experience. Therefore, the science teachers admitted that integrating the technicality strategies into their teaching was the easiest and most comfortable.

This is not to say that teachers did not value what they learned about abstraction, density and genres in science language. When presented with the concepts of abstraction, density, and genres, the teachers agreed with the postulate that these were reasons that science reading could be a challenge for students. However, these concepts were more distant from their prior knowledge of teaching reading in science and therefore the science teachers were more tentative about using the ideas with their students. In addition, the teachers' lack of confidence in their own knowledge of grammar in English influenced their implementation processes. Finally, the issue of time continued to impact the science teachers' ability to plan, implement, and reflect on what they were learning about science language. However, even though the teachers struggled with the integration of these strategies into their teaching, all seven of the teachers were excited about learning about the features of science language and reported they would revisit the ideas and incorporate them more in the future.

Conclusion

This chapter illuminated the experiences of the science teachers as they participated in the professional development modules. Teachers were excited to learn about disciplinary reading practices in science. The science teachers had a raised awareness now about how the features of science language posed challenges to readers and could contribute to why students did not want to read science texts. After learning about the features of science language, the teachers felt they were equipped with a new set of tools to help their students.

The science teachers demonstrated an emerging understanding about the complexity of science language. The teachers embraced learning about technicality, abstractions, density, and genres and willingly tried strategies in their classrooms to address each feature. Chapter 7 will address the influences on how the science teachers learned about the specialized features of science language.

Table 6-1. Density Sample

Pre modifiers	During facilitated diffusion
Head noun	Molecules
Postmodifiers	Such as glucose
	That cannot diffuse across the cell membrane's lipid bilayer
	On their own

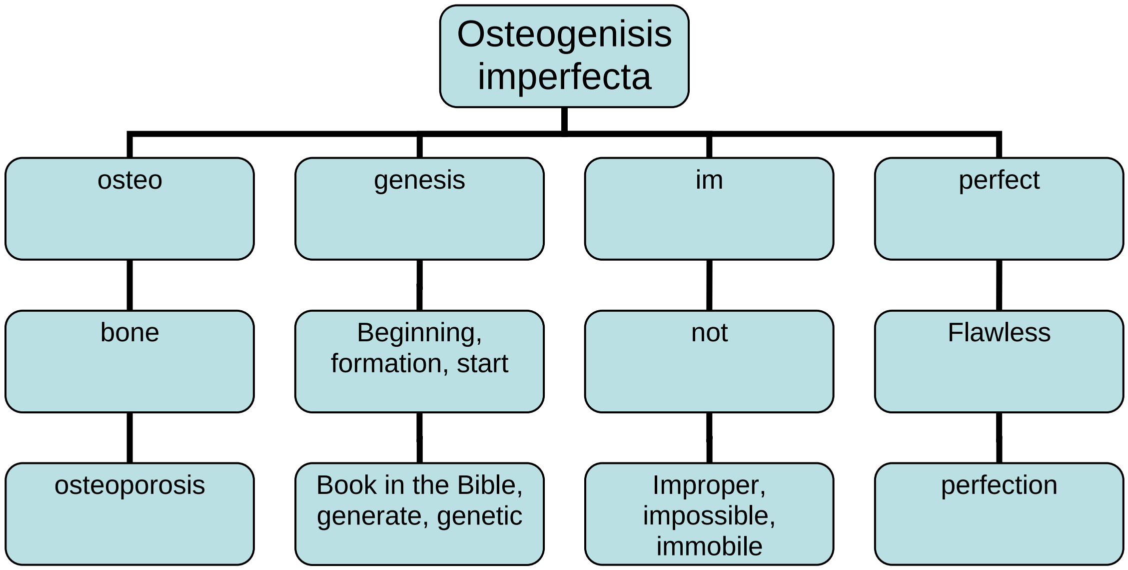

Figure 6-1. Casey's Concept Map

CHAPTER 7
DISCUSSION

The purpose of this chapter is to discuss how secondary science teachers' learn about the specialized language of science and apply it to the teaching of reading in science. In this chapter I will articulate the relationship between the influences that either supported or interfered with the process of science teachers' learning and integrating teaching strategies into their instructional routines. Chapters 5 and 6 articulated the teachers' prior concepts associated with reading in science and what the teachers learned in the professional development modules. Further analysis shed light on what impacts the learning process of secondary science teachers in their study of science language. This chapter is organized into three sections: (a) theorizing about teacher learning (b) implications and (c) future research.

Theorizing about Teacher Learning

In order to portray the grounded theory of how secondary science teachers learn about the specialized language of science and apply it to their teaching, a model was created to show the interrelationship between the influences on teacher's learning and integration. This model serves to explain the influences that either facilitated or inhibited science teachers' learning. Figure 7-1 illustrates the grounded theory which shows the interplay between (a) the three systems: the individual, the professional development program, and the school context and (b) the core concept: *opportunity to talk*. Within each system, various components contributed to the nature of the core concept: *opportunity to talk*.

The core concept, *opportunity to talk* emerged as the most influential factor in how the science teachers learned about the features of science language. Data showed that the teachers highly valued time to talk about what they were learning. Having an opportunity to talk about the distinct features of science language impacted the science teachers' evaluation of information, their decisions about implementation, and their assessment of instruction.

The concept of *opportunity to talk* is multifaceted. On one level, the science teachers addressed the importance of the *content* of their talk including talk about the new information, talk about how to implement it into the classroom, and talk about how the lessons were executed in the classroom. On another level, the science teachers addressed the importance of *who they were talking to* including other science teachers who were participating in the workshop, fellow science teachers, and me-the facilitator. On a third level, the teachers addressed the *context* of these conversations including formal settings like the professional development meetings or scheduled one-on-one meetings with me or informal settings like in the teachers' lounge, at lunch, catching me in the hallway between classes, or email communications.

Figure 7.1 illustrates the grounded theory model on how secondary science teachers learn about science language. The core concept *opportunity to talk is* represented at the intersection of the three concentric circles, each representing a system that influenced the nature of the core concept. These three systems (a) the individual, (b) the professional development, and (c) the school context contain various influences within that impact the process of learning about science language. Each system can exist independently or in congruence with the others therefore, the circles are represented independently and intertwined. However, it is through the interaction of the systems that the *opportunity to talk* is created and in turn the process of learning is impacted.

The circles are connected to the core concept with arrows in either direction to represent the fluid nature of these intersections. Though we can draw conclusions across cases about the learning process of the science teachers, it is important to acknowledge the unique nature of learning each science teacher engages in during this process of learning. Therefore, the lines and arrows between the systems and the core concept represent the fluid and unpredictable movements of the circles as they intersect. At anytime the components within each system can have greater or less influence on the *opportunity to talk* and essentially on the science teachers' learning process.

Description of Systems

Each system is labeled as an *opportunity* because the variables combine in that system to offer an opportunity, or time, for learning to happen for the science teachers. The three labels are (a) The individual: *opportunity to examine*, (b) The professional development: *opportunity to learn*, and (c) The school context: *opportunity to practice*. To begin, I will describe each system and its variables.

The system of the individual is made up of the following components: (a) prior knowledge, (b) prior experiences, (c) beliefs, (d) attitudes, (e) goals for teaching, and (f) knowledge acquisition. These components are all part of the individual teacher's beginning frame of reference. In this case, identification of these influences provides insight into each science teacher's perception about the role of reading in the secondary science classroom. This system is labeled *opportunity to examine* because it is through the interaction with the core concept of *opportunity to talk* that the science teachers examine their own personal constructs and determine how those constructs interact with the other systems in the model to influence their process of learning about science language. For example, Casey''s prior knowledge about the word abstraction interfered with her understanding of how abstraction was used to theorize in science writing. She examined her prior knowledge of abstraction by comparing what she knew to the discussion of abstraction in science language that happened in the professional development setting to reframe her understanding about abstraction. In another case, Bette reported how her experience taking classes in medical terminology convinced her of the necessity of knowing the definitions of root words and affixes to be able to analyze technical words in science. So, when the topic of technicality was addressed in the workshop, Bette moved easily into adopting practices into her classroom to teach students how to analyze words by the word parts. The new information from the professional development reinforced her prior knowledge and experience and gave her tools to help her students learn.

The system of professional development is labeled *opportunity to learn* because it affords the teachers the time to study and think about relevant information pertaining to science language and reading. Professional development includes the following components: (a) expert knowledge, and (b) facilitator. The first component, expert knowledge, includes the books, articles, and presentations that the science teachers' review in order to access knowledge about the specialized language of science. In this case, another important point is that the information was discipline-focused. The books, articles, and presentations centered on science and reading.

Another component of the professional development system is the facilitator. The facilitator links the expertise from the field to the expertise of the classroom teachers. By providing articles, books, and information to the teachers about reading and science, the facilitator sets the stage for opportunities for the science teachers to engage in learning about the complexity of science language. In addition, the facilitator demonstrates lessons to show the science teachers how the ideas and strategies from the literature work. The facilitator serves in various roles to support the teachers' learning. For example, in this study I served in the professional development modules to present information and monitor discussions and in the classrooms I served as a participant-observer, co-teacher, and demonstrator.

The components from the professional development system interact with the core concept of *opportunity to talk* in various ways. First of all, the professional development system provides a context in which the opportunity to talk can exist. As the teachers learn about the ideas from the content of the professional development modules, they then discuss what they are learning with their peers and the facilitator. For example, when I presented a strategy like sentence completion when we were learning about abstraction, the science teachers talked about how they thought through the process of doing the exercise, comparing answers with one another and thinking out loud about how it could be used in the science classroom.

The final system is the school context which also includes the classroom. The general school context includes administrator support and school culture. In this case, the administration encouraged the science teachers to be a part of this study. In addition, the administration provided opportunities for teachers to meet in book study groups and attend state level conferences. Also, the school culture was safe and orderly, creating an atmosphere conducive to learning and teaching.

The classroom contains the components of student learning and teacher integration. This system is represented within the school context circle because it exists within the school context and is influenced by the administrative support and school climate. This system is labeled *opportunity to practice* because it is within this system that teachers integrate the lessons about the specialized language of science and determine the efficacy of the approach. Student learning is a key component of the classroom because if the teacher perceived that students were learning, they responded positively to the strategies. The relationship between the classroom and the core concept works in two directions. For example, Brad tried a technicality lesson in his classroom to get his students to analyze the word classification. He was pleased with the students' response to the strategy and perceived that it improved their learning. When Brad met with the group of teachers during the professional development meeting, he then shared his experience using the technicality strategy in his classroom. This scenario represents the flow from the system of the classroom to the core concept. In turn, when Brad shared, Billie listened to his experience and then took it back to her classroom and used the same strategy. In this case, the flow moved from the core concept of *opportunities to talk about practice* to the system of the classroom.

This grounded theory model represents the interrelationships between the three systems: the individual, the professional development, and the school context. When these systems interact the most influential factor on science teachers' learning was the *opportunity to talk*. The components of each system interacted with the core concept to influence the content and context of the talk that in turn influenced the levels of teacher learning and integration of the specialized language of science. The following sections will provide greater detail about the core concept and how the components from each of the systems interact with the core concept to either facilitate or hinder the process of learning.

Core Concept: Opportunities to Talk About Practice

Evidence from data analysis showed that the science teachers in this study valued having the *opportunity to talk* about what they were learning about science language and how they were integrating it in their classroom. The *opportunity to talk* proved to be the greatest contributor to how the science teachers acquired knowledge. The composition of *opportunity to talk* included the location, the content, and the participants. Figure 7.2 shows the model of the core concept of *opportunity to talk*.

The first component to consider is the location of the opportunity to talk. The science teachers talked about the importance of talking about their learning in both formal and informal settings. The breadth of the data collected addressed the formal setting of the professional development sessions or a planned meeting with me, the facilitator. These formal settings served as the impetus for other places where opportunities to talk emerged. Interestingly, a small amount of data also indicated that informal settings like spontaneous conversations in the hallway or email communications also influenced the science teachers' learning process.

The professional development system however emerged as the most influential location because it created the context for the *opportunity to talk* to happen. The science teachers repeatedly acknowledged how talking with one another during the professional development meetings was useful. Patsy commented during her final interview, “I feel the discussions are definitely helpful” (FI-PB-20). Within this system, the time was set aside for the teachers to talk about what they were learning. The learning generated in the discussion would then carry over to other contexts for opportunities to talk to occur such as with a facilitator during a conference or with a colleague over lunch.

For the science teachers, the opportunities to talk during the professional development modules is where teachers made decisions about the usefulness of a concept presented during the workshops. The teachers indicated that listening to one another share stories about integration influenced their decisions to try an idea in their classroom. The science teachers also said that talking about the concepts with one another helped them to make sense out of what they were learning. In addition, listening to each other influenced teachers’ confidence levels. If another teacher struggled with implementing an idea, the science teachers appreciated hearing the story. Sharing both successes and failures supported the science teachers’ learning process.

An influencing factor in the professional development modules was the format. The format was significant in facilitating the opportunity for the science teachers to talk about their learning. The science teachers addressed conditions of the format such as the size of the group and the background of the teachers as influential to their willingness to share and learn. That the teachers were all from the same school and they all taught science proved to be significant. Because the science teachers all knew one another prior to the study, they felt comfortable sharing ideas and experiences with one another. Mona articulated the importance of this during her mid-term interview:

> It's [the professional development modules] been nicely organized and friendly. We all know each other which is a big change. Most of my classes are not like that. I might be the only one from my school and some I've been the only one from my school district. So that's a big difference too. I really like the fact that we are all working on this together. It's really been nice. (MT-BM-6)

Bette also agreed that the format of the workshop influenced her involvement with learning about the content of the professional development modules. For Bette, the small group setting was different from other experiences she has had in workshop settings.

> But I liked it. It was good. I think a lot of times teachers may be doing stuff and not even know the terms. But knowing the terms and then really seeing it play out you know in a workshop and then with your class and then coming back and discussing, "How did it go?" and hearing from other people, I think that was good to see how things worked out. But yeah, compared to other workshops like I said I don't even really recall what *[chuckling]* –what the other ones were really about. So formal versus informal, I like smaller groups or if it's a large workshop it's gotta be someone who is – who knows what they are talking about and someone who will keep the attention of the teachers. Because teachers don't wanna be in a big boring workshop that tells them the same things they heard a year ago but forgot because it was too much information at the time. (MT-JB-8)

Bette's comment also raised a point about liking the structure of the format: learning about a topic, practicing it in the classroom, and then returning to the group for feedback. Casey echoed Bette's viewpoint in the following statement form her final interview:

> I liked the format of the workshop, where we discussed and learned about one of the reasons why reading science is different. We learned about it our self and became aware of it, and then the application format, where you could then try the strategy and put it into – use it, so to speak. I like that format. (FI-MC-4)

This format of introducing an idea, discussing it, planning to use it, and then sharing the results supported the teachers' learning about science language and applying it to teaching reading in science. The science teachers valued the time during the professional development sessions to discuss the new information and hear from one another about the implementation process. When teachers were presented with a new idea during the professional development sessions, they had an opportunity to discuss the validity of the idea and how it might impact their teaching. They were then presented with a model lesson about how to integrate the concept into their teaching. Teachers actually participated in the lessons as students and had an opportunity to talk about how they interpreted the lesson. After trying the lesson, teachers were given the opportunity to plan together. Finally, after the teacher had implemented the lessons, they had the opportunity during the next meeting to share their experiences with the group.

Informal locations also played a role in setting the stage for opportunities to talk. There was a small amount of evidence that teachers also were talking about the ideas from the workshop with one another or other colleagues in settings outside of the workshop. For example, in a professional development meeting, Bette and Billie shared a story about Bette watching Billie do a lesson when she used the morphemic analysis to dissect the word *semi-conductor*. Bette told the group that it was helpful to watch Billie and see her doing the lesson. Bette further commented during an interview about where she learns about ideas for the classroom. She said. “I know that I get a lot of what I do from other teachers. I ask. I think that's the best way to learn. You know just ask people at lunch, "Hey, what's the best way you teach vocab?” (MT-JB-6).

In another instance, Mona shared that she used email to talk about idea with colleagues. She sent me a copy of an email that she had distributed to her colleagues who were teaching physical science. In an email communication she attached three samples and wrote:

> Hi,
> Billie and I have been in a group that's working on reading in science. One of the exercises we've tried is reading modeling for sentence completion. I've made a couple of these sentence completion exercises that received good student response and wanted to share with you. (EC-11/19/08)

The teachers also used this setting to communicate with me about their lesson planning and responses to what they were learning about the specialized language of science. For example, Patsy sent an email describing her implementation of a strategy:

> We used sentence transformation to break down and analyze some very technical concepts. Every one admitted that before the discussion, they had no idea what the words meant. They had read and reread the description many times on their own. But after our discussion (and the sentence transformation) where they broke the content down and analyzed it, then put it into their own words (or listened and internalized to the other students), that the Calvin Cycle was able to be understood after all. Yeah! Mission accomplished! This skill will serve them oh so well in college!!! (EC-PB-11/12/08)

The location of the opportunity to talk varied. While the formal setting of the professional development was the most significant, informal settings like teachers classrooms and email communications also served to provide places where teachers could talk about their learning.

Another significant factor that facilitated the teachers' learning during the opportunities to talk was the content of the discussions. Through data analysis, three areas of talk were identified: (a) talking about concepts, (b) talking about planning for instruction, and (c) talking about implementation. The first area, talking about concepts, gave the teachers an opportunity to examine the professional literature and examples and talk about their interpretations and evaluations of the material. For example, during the professional development module about genres, the science teachers read about genres in science reading and then were provided with examples of the types of genres. The science teachers then worked together to analyze excerpts of science text. In response to the genre information, Patsy stated: “I definitely liked with the genres, when you gave us the examples and then allowed us the opportunity to discuss them” (FI-PB-23).

The next topic identified in the analysis was talk about planning for instruction. During planning, several factors interacted to influence the talk about practice. Evidence of teachers’ analyzing prior knowledge, referring to expert knowledge, and thinking about goals for student learning were seen. For example, Brad said he liked hearing what his peers had to say during planning so that he had a clearer sense of how to do it in his own classroom. Brad used this time to think about his own interpretations of the expert knowledge and his own experiences in teaching a particular idea to plan for how he was going to implement an idea that he believed could impact student learning. In an interview Brad explained, “Yeah, you just-, you bounce ideas off each other in planning and stuff like that, where it’s, like, ‘oh, what do you do?’ or ‘what do you do?, and if I get a good idea, I’m, like, okay. You know, and then it’s just implementing it” (FI-MB-12).

Patsy also valued the opportunities to talk about planning during the professional development modules. During her final interview she shared that the opportunities to talk during the planning stage was useful to her. She appreciated the time to hear what other teachers were doing because it is a rare part of high school teaching to have a chance to talk with your peers about planning lessons.

> I’ve always been a proponent for networking. To have the opportunity to sit down with my fellow science teachers and say, “Well, what works for you?

> Oh, well I could change that for biology and work it in and see if that works for my students. I'm so big on networking, and I think it's a shame that they don't give us that opportunity as much, you know. Not in high school. I think they're better at that at elementary when they have teams. And I think that's something that we lose when we are at the secondary level. We work independently on planning our lessons, but we don't work as a team." And so I think that that's something that we kind of lose. (FI-PB-20)

Evidence from the professional development sessions showed that the science teachers used that time to think about how the strategies could be used in their classrooms. For example, when we talked about genres, the science teachers discussed ways they could address genres in their classrooms.

> **Bette:** Yeah, but also, as I was reading through this page 27, just the whole preparation part where it says collect sample, I think that's huge. That's where, as a teacher, I need to kind of really work on that is collecting samples, just being proactive and looking outside of my textbook to go to the internet and articles and stuff like that, you know, to really pull some examples.
>
> **Billie:** You could take even like my weekly news – I just read this note for myself, but the weekly news article that I have my kids did pick a couple of these that would typically be in like an online internet because some of them could be multiple ones or whatever and talk to them about it and then okay, these are your choices. Why did you pick this? Explain. Give me supporting information about – kind of like we did verbally but have them write about that with their, you know, they find the article that interests them, but then they have to choose which genre it is or whatever, like we did, and write about it, you know, a paragraph or whatever, something short.
>
> **Lisa:** At first as we were thinking about this, my first thought was just on procedures, so I can give the students even examples in the book. This is the subject. Now how are we gonna study it? And I have done that already a couple of times this year, so this would not be new, but the business about discussion, exposition, you know, all that, that would be a little bit new. But procedures wouldn't be, so I feel really comfortable with that.
>
> **Casey:** So we can pick just one, expose them to that and then eventually – and then have them write, get to the point of their writing it rather than exposing them to all of them?
>
> **Patsy:** I think they've seen them separately, these ideas. I think it would be neat to do two that are related, like procedures and recounts or like

> exposition and discussion. I think that would be easy to – not easy, but I would, you know, somewhat easily tell my kids, “Okay you know how sometimes you know, they talk about persuasive writing, well in science exposition means this. We’re giving information, but we’re kind of skewing the purpose behind it one way to get you to feel this certain way about this, you know, and believe this, whereas discussion, we’re gonna talk about both sides of the story,” you know, what whole, you know, I think it would be better for me to do it that way with my kids. I think we would understand. Otherwise, it’s just like, “Okay, this is a discussion or this is you know another one.
>
> **Bette:** Yeah, and then what you could do is you can say, “Okay, well what are the words there that make you see that they’re,” like Lisa, when you were reading that one that you diagnosed as exposition, you picked up specific words that were convincing you that this person was trying to persuade you that an ecosystem was – you know, a certain way they’re trying to get you to believe something. So again, that – putting them side by side can allow you to take that focus of, well how’s the language different in this,”

Billie also valued being able to share ideas with her peers. She felt when she heard a fellow teacher talk about how to use an idea in a particular area of science, then she could think more easily about how to apply it to her own lessons. She described how hearing Brad talk about genres was useful to her:

> I liked when we all got together, because, again, I do physical science. So some of it was nice to see how other people used it in their area, because it wasn’t all physical science. You know, biology – even though it was a biology teacher, you know, when Brad used some examples of genres or something that he did, then I was, like, oh, well, that sounds so easy. (FI-JTB-12)

The final topic of talk was implementation. In this setting the dominant influence was student learning. The teachers shared the successes and challenges of their lessons. The science teachers found it worthwhile to talk about the process of implementing the strategies once the lessons were delivered. Listening to the experiences of another teacher helped the science teachers evaluate their own success at implementing the ideas. For example, Billie commented:

> So once we were together and talked about it, you develop somewhat of a better understanding, because you're, like, oh, I could have done that one. When we got together and were able to meet and talk about what worked, what didn't work, difficulties- that helped because we all didn't have the same experience with it. Some people were, like, oh, that's so easy and other people were, like, yeah, had a little trouble with that one (FI-JTB-20).

Bette also commented about how listening to her peers helped her to better understand the information about science language. She said:

> Getting in the group settings is great because everybody shares how it impacted them and you're like, "Well I didn't see it that way." And when you hear everybody's little like oh this is what happened in my class you can kind of see how those little puzzle pieces fit together. (MT-JB-8)

Lisa echoed the sentiment that getting together to share ideas was important to her inhelping her make sense of how the new ideas fit into her teaching repertoire. She stated, "It put us in contact with each other which to me is extremely important to share ideas and find out what's working and figure out the things that were universally working for us" (MT-VL-18). Bette also valued the feedback from her peers, "I definitely think, when other teachers gave examples of what they did and how they used these tools in the class- that was good for me to hear that. I actually did pull a couple of their activities and use them for myself" (FI-JB-8).

Having the opportunity to talk about science language and how to bring it into the classroom was important to the science teachers. Being able to discuss the new ideas and the experiences of implementing lessons into the classroom influenced how the teachers' learned about the concepts and then took them into their classrooms. Mona clearly summarized this point during her final interview when she said:

> Probably more understanding came from our group discussions than from any other single source. Having the slides in front of us of course is a big help. But listening to what the other teachers have done; what they found successful; what they think could be changed, that was worth it. (FI-BM-7)

The final aspect of the *opportunity to talk* that was important was the participants. Who was involved in the discussions impacted the science teachers' learning. First of all, the science teachers valued hearing ideas from one another. In the final professional development meeting, Lisa shared her feelings about the experience with her peers. Having the opportunity to talk with her peers was influential in her learning process.

> And I just want to add I just love being here with all you guys because you push my envelope all over the place. Saying that's a cool idea, I didn't think about that, demystify science. *(Laughter)* That just popped through my head and I get very tired and jaded doing the same old thing about the end of the day I'm like, "Oh God." And a lot of this is just I've never thought about doing that. So it's been good for me to get reflective and to change a few things. (PD-VL-04-21)

The next participant that influenced the opportunities to talk was the interactions between the facilitator and the science teachers. As the facilitator, I had an opportunity to be a part of the science teachers' process of learning. Data showed that the science teachers valued the role I played in facilitating the opportunities to talk during the professional development meetings. When the teachers felt that their ideas were valued, they felt comfortable in sharing and talking during the meetings. Each week I summarized what the teachers had talked about during the previous professional development meeting and posted it on the overhead for review. Lisa commented about this practice when she said:

> And then the fact that you're listening to what we say and giving us feedback. When you gave us the handout last week that's like "Here's what you said" – it's like oh, I do have value. Even more feedback. You're handling all of us testy at the end of the day people very well. (FI-VL-9)

Another aspect of how I facilitated talk was in providing time for the science teachers to process their understanding with one another by either responding to a concept or practicing a lesson. For example, when we would read about a topic, like abstraction, I might present an idea to them like: "Abstract nouns like *discovery* and *significance* help an author to write on a theoretical level." Then I would ask them to talk about it. Patsy shared her response to this strategy:

> I feel the discussions are definitely helpful. I like the fact that sometimes you let us struggle, you know, and because you know these things and we don't, we're like not a clue. Okay, well what – let's try to make some sense out of this. And so I thought that was good to, that you didn't always give us all the information right away, that you kind made us dig for it because that's a challenge for us, and we like to be challenged. (FI-PB-20)

Following is an excerpt from the session about abstraction in science language. As the facilitator, I worked with the teachers to understand what thinking processes they were using as they considered which words fit into the sentence completion exercise. This is the conversation that happened after the science teachers participated as students in a demonstration lesson.

> **Facilitator:** That is that during part of reading part that is hard to get kids to do. See this really, when he expresses thoughts you see, think about what his mind went through. Anyone else want to share kind of went their mind through and what they think?
>
> **Casey:** The key thing for me on this is I immediately think onto migration because of the head north. That just smacked me right upside the head that there was a very specific word dealing with what should go in the blank because heading north or heading south indicates by its very nature the word migration.
>
> **Facilitator:** Right.
>
> **Bette:** And then after – I'm like Casey. So after I said migration I thought, "Well, maybe that's too easy." So I went back and looked to see if there was something more appropriate that would also equally well fit in there. And I couldn't find anything I liked as well as migration. And of course, being a science teacher I'm looking for a scientific term where- I think sometimes with kids when they see a blank they just want to slap any word in there. They'll go into traveling is long and dangerous. Eating is long and dangerous. Swimming is long and dangerous. Or the journey is long and dangerous. Just to get a word or phrase or something in there without really taking a moment to stop and think about heading north and what that,

> you know indicates in there. They want to get the item finished. I'll stop at word that is good but not necessarily appropriate or best.
>
> **Facilitator:** One thing that you've really raised here is that kids are used to the very traditional, "what's the right word? What's the right word I've got to put in here?" They're not looking to think about it. And we heard that a couple times with yours yesterday.
>
> **Mona:** We sure did.
>
> **Facilitator:** I think I wrote down six times yesterday when kids said, "What's the right word? What's the right word that I have to have in there?" So this is stressful to them. And that's why it takes a little bit of coaching for them to start to think differently. And you can even take some of these like that might not necessarily be related to what you're doing, where you find things to get them to just start focusing on language. Cause maybe if you take one like this to give them as an example and do it the first like five minutes of class, they're not gonna feel threatened by it because it's not about your topic. But it's like a daily kind of oral, a little language exercise. You could do it for a couple weeks and then move them into things that are more related to your topic. But what this does is it takes the focus off of the right word and gets them to start looking at the language. You can start having conversations about, well scientists, anybody who writes, picks very specific words to try to explain something. The word used in this is the northbound journey. This is from a textbook. But all those other words make sense. (PD4-12/9-9)

Another way the facilitator influenced the opportunities to talk was through providing model lessons for the teachers. This gave the teachers a chance to participate in the lesson as a learner and then talk about the strategy and its usefulness. Billie commented about how having an opportunity to talk with each other while they did practice lessons was useful to her.

> You know how you gave us those examples that we worked through the last time and that – okay now I see how the students could have done this 'cause we all came up with different answers. You know the students are gonna do the same thing. (MT-JTB-8)

The facilitator also impacted the opportunities to talk outside of the professional development sessions. For example, the opportunity to talk about a lesson either during or after the implementation influenced the science teachers' learning about the specialized language of science. In the following example, Patsy shared during an interview how I had helped her think about how to respond to a student who asked a question about a technical word. In this case, the student asked her to explain the word *surrogate* as it appeared in a sentence referring to a cat as a surrogate mother in an article about a wildcat.

> Remember you talked me through that the one day with the one question that Derrick had asked about what you think that surrogate means. Well look on the next page and the next paragraph; let's look at that and now do you have a better feel for what it might mean instead of just here's the dictionary, let's look it up. (MT-PB-1)

Being involved in the classrooms allowed me to have time to talk to the teachers about their lessons and participate in the teaching process. Brad described how my presence in the classroom encouraged him to try the lessons. Before each lesson we delivered together, we had an opportunity to talk about it and then after we had a chance to process it. During the study we co-taught four lessons. Brad responded to this in his interview:

> For me, the best thing was having you – and, you know, I did some things myself, but when – and, you know, sometimes we're too hard headed to ask, but when you came in and I realized that, oh, yes, she has no problem getting up and teaching this stuff, cause me seeing it in action with kids is more helpful to me. (FI-MB-9)

In addition, spontaneous conversations in the hallway or lounge supported the teachers' endeavors in implementing the strategies into their classrooms. For example, Casey stopped me in the hall one day to share with me about her technicality lesson. I asked her to compare how the lesson that she did using a word analysis map differed from previous ways that she addressed technical words in science. She said, "I used to give the kids a list of words to memorize but I like this because they are more involved in breaking it down." We continued to talk about how the lesson allowed the students to become more involved in understanding the language of science. Meeting in the hallway was an opportune time when the lesson was fresh in her mind to think about the lesson (FN-10-27-08).

In another instance, Brad shared with me that he did not understand how to find words for abstraction. During his midterm interview, he shared his confusion about the concept.

> We've gone over that – we modeled that twice in class, and then we talked about it a lot in our meeting. I just have a hard time implementing that into class, because – because when we read through the paragraphs and we were pointing out what kind of word it is, I'm just not even sure what kind of word it is myself. (MT-MB-6)

We then met during his planning period and looked through his textbook for examples. I explained that the big mistake I was noticing was that teachers were choosing technical words that were hard to reword instead of science words that were abstract nouns and could be broken down and explained through reference to other parts of the text. We looked at a sentence in his textbook that contained the words *blastula* and *formation*. We discussed how formation summarized the previous part of the text but blastula was a specific word for science with a particular definition. This opportunity to talk gave Brad a chance to ask questions and receive feedback from me. (FN-12-08-08).

Being able to meet with a facilitator and have an opportunity to talk about the strategies was important to the science teachers. Receiving feedback about their lesson implementation and their understanding of the concepts supported the teachers' learning about the specialized language of science. When asked about what was the most influential to her learning process during her midterm interviews, Casey responded, "I guess if you had to pick one thing as being most important it would be the feedback. Cause typically it's just you go to a workshop, they show you something, you try it and that's kind of it, yeah. So yeah, I think the feedback is really good" (MT-MC-4).

The *opportunity to talk* emerged in the data as the most important influence on how the science teachers learned about the specialized language of science. Without opportunities to talk about practice, the science teachers' level of learning would not have been as substantial. In the same regard, the level of learning could have been improved with increased opportunities to talk and improvement in the quality of talk. Four other factors also emerged in the data as influential to the science teachers' learning process: (a) time (b) motivation to learn, (c) prior knowledge, (d) access to expert knowledge. The following section will illuminate how these component concepts interacted to either support or inhibit the science teachers' learning.

Motivation to Learn

Motivation to learn was a component of the individual system. This component was influenced by and interacted with the opportunities to talk to impact the science teachers learning about the specialized language of science. The component of motivation to learn includes teachers' goals for student learning and their perceived value of the information in the professional development sessions.

To begin, the science teachers started this journey in learning about the specialized language of science with motivation to know about better ways to help their students improve their reading in science. In her personal statement Bette wrote, "I would like to learn new reading strategies for technical reading, reading for content so I can help my students, especially my lower levels" (PS-JB-5). Casey wrote, "I hope to gain specific strategies to enhance my students reading comprehension of science information" (PS-MC-5). And Mona stated she was interested in "helping my students move to higher levels in reading" and especially in finding "new reasons doing reading – for comprehension rather than fluency" (BPS-BM-5).

Patsy elaborated in her mid-term interview about her motivation to be a part of the study. She emphasized the goal of helping students improve their reading for life-long learning.

> I think it's essential that as foundational teachers here in high school, we prepare them for that, and give them the tools so they can be successful. And those who don't go on to college are still gonna have to read a proposition to vote on. They're still gonna have to break it down and understand. And if we give them those tools, then that helps them to become a better citizen for our society. (FI-PB-10)

The science teachers approached the professional development with motivation to help their students become better readers of science. This motivation was maintained and supported through their interaction with other teachers during their opportunities to talk during the professional development meetings. The science teachers were motivated by the ideas and experiences shared by other teachers. For example, Lisa explained her view on how the group worked together to motivate one another:

> The group, we sort of morphed into one as opposed to being disparate as we came in. And okay they teach this and I teach that and pretty soon we're like I tried this; it worked really well. Oh that – I didn't think about that one. And I liked sparking off of other teachers (FI-VL-8).

Another influence on teachers' motivation was their perception that the information they were learning was useful to their teaching. One reason the science teachers were motivated by the content of the professional development modules was due to the disciplinary-focus of the material. The science teachers valued that the content of the professional development was focused on science. Chapter 5 addressed that many of these teachers had experiences learning about reading in the content areas that addressed generalized strategies and then the teachers were left to figure out how to apply the ideas on their own to reading in science. Casey compared her experience in other workshops to this one and said, “I think that what we learned about in this workshop, these strategies are more specific for science” (MT-MC-4).

The science teachers thought it was useful in this professional development experience that the information they were learning about science language was content focused. For example, Billie explained how she liked the focus on science because she could see the direct application to her own teaching.

> I would say I like this because it’s I haven’t really had any workshops that were content, true content oriented. They might have been content oriented in the sense that they talked about some things you could do in other fields, but this kinda broke it down more specific in ‘Okay this is the reason kids struggle, these are the things that they do to the wording and the vocabulary and the language that make it hard for kids to read in science’ then I think, ‘Oh- I get that.’ (MT-JTB-3)

Bette also commented about the usefulness of the information being specific to science. Due to the nature of science language, she felt it was important to address the reading in science separately from other content areas.

> But with the tools and things that we talked about, it was, like, specific, a lot more specific. Not that you couldn’t use those same things in other areas, but the stuff we talked about was science specific, because it is more complicated and it is more informational, shoved into one little space. So I think it’s definitely very helpful to do the content specific, because even if you did one with history, it’s gonna be different than you would with science, cause there’s gonna be pieces that vary. (FI-JB-9)

The science teachers continued to be motivated throughout the professional development training because they believed the information they were learning was easily and appropriately applicable to their teaching of science. Patsy summarized the value she found in the new strategies she learned through the professional development:

> And as a teacher you are aware that they don't all love science. And some of them, they'll say, "Ms. Patsy, it's nothing personal. I just don't like science." And so that, to me, is a goal that I try to change that for them. And I think giving them the understanding, the tools, the – some of the strategies that I've learned will help with that. (FI-PB-9).

Lisa also described how what she was learning supported her desire to help students improve their reading.

> And this was so indescribably helpful and that with all the FCAT pressure on us to help these children even with FCAT, science, reading and writing you feel helpless because you don't have the tools or the clues or know where to go. It's like okay we have to change out the engine in the car but I don't know which screwdrivers to use, this kind of thing. And this gave us a whole box full of tools that are eminently useable. I really feel more empowered to help the students deal with all these aspects. (FI-VL-4)

Billie expressed her motivation to continue trying to implement the ideas into her classroom beyond the ending of the professional development.

> I feel like regardless of the total outcome I'm gonna walk away with tools to help my students. It may not be a perfect year this year with it, but at least as the year progresses I can integrate a lot of the stuff into what I'm already doing and it's not like, it's not that much extra. A bell activity maybe instead of two or three minutes it takes five, but in the end it's a concept they understand instead of a vocab definition (MT-JB-8)

The component of motivation to learn was influential on the teachers learning about the specialized features of science language. The teachers entered the study with a desire to gain knowledge about how to help their students improve their reading. They maintained their motivation by listening to one another during the professional development meetings and perceiving that the information they were learning was valuable to their teaching.

Prior Knowledge

Prior knowledge served as another influential construct in the system of the individual. When the science teachers learned about the concepts of technicality, abstraction, density, and genres, their prior knowledge of these ideas impacted their understanding of the topic. For example, the topic of technicality was closely related to teachers' prior knowledge of vocabulary so the teachers' expressed ease in integrating strategies for coping with technicality into their teaching. However, the topic of abstraction was challenging because the science teachers' prior knowledge about abstraction hindered their new understanding about how the concept related to science language. Casey commented that she struggled to get past the notion that abstract did not just mean an idea that you could not see but a way that scientists manipulated the language to continue talking about an important concept.

One area that was particularly challenging to the teachers was identifying grammatical structures used in science language. Teachers lacked confidence in their own knowledge of grammar and felt this hindered their understanding, especially of the features of density and genres. When teachers talks about density, they often did not address the embedded clauses and when probed about why, talked about their level of comfort with teaching grammar. Bette even commented that if the English teachers would teach the grammar, then in science the teachers could just talk about it and students could already get the grammar part of it. The science teachers understood how the grammatical features played a role in the structure of science language when it was discussed and pointed out during the professional development modules, however, they were reluctant to teach about the grammatical structures in their own classrooms. Billie even mentioned she wished she would have paid better attention in English class so that she better understood grammar and could talk to her students about declarative sentences and embedded clauses. The teachers' prior knowledge about grammar in English served to hinder their understanding of how language functioned in science.

Prior knowledge therefore either served to facilitate or inhibit the science teachers' process of learning about the specialized language of science. When their prior knowledge was closely associated with an idea, like vocabulary to technicality, the teachers' prior knowledge complimented their learning. However, when teachers' prior knowledge was lacking, they struggled to understand. For example, when they were faced with applying their knowledge of grammar to their understanding of science language, they were less comfortable and required much more support in developing their confidence and understanding.

Access to Knowledge

Another component that influenced the teachers learning was their access to expert knowledge. The science teachers appreciated reading information from experts in the field of science and literacy that addressed the issues of reading in science. Brad commented during his mid-term interview that, "I really enjoy the articles you gave us and the book" (MT-MB-6). Knowing that the information being reviewed in the professional development modules was supported by experts in the field was important to the science teachers. Billie explained how the knowledge from the experts helped to clarify the purpose for integrating the lessons into the classroom. She said:

> I think the knowledge building is important, because you feel more confident about why [you are doing the strategies] It's kind of, like, having the purpose for reading. You know, I need the purpose for why I'm teaching this. But I don't – I think – again, if you don't give that background information, that why do I care – You know, why – why is this important? Why do I have to teach this and why do I have to teach reading? (FI-JTB-20)

The science teachers not only felt that the expert knowledge supported why they should incorporate strategies to address science language into their teaching, but also because it clarified their understanding of the theory of functional language analysis. Bette commented that the author of the article she read helped her to see the big picture of how looking at science from a language perspective is useful.

> As far as the textbooks that we're given, when we read about how language is looked at in science, that was – I think the authors did a great job of kind of just putting in words, what's going on nowadays with science literature and where we're going and how it's gonna be looked at later. I appreciate the literature that we saw, the articles we read. (FI-JB-8)

Mona further iterated the value she found in having access to the expert knowledge. She explained that she liked being able to link the knowledge with the practice. "I think the biggest thing is reading these theoretical explanations. It has always been interesting. But this is the first time I've seen so much I can take into the classroom with me; and that's a first." (FI-BM-7) Lisa also believed the readings were helpful to supporting her learning, "I feel the readings reinforce what I have observed over 30 + years of teaching science" (EM-VL-10-08-08).

One teacher actually described how she went back to consult the articles after attending the professional development meetings. Patsy explained, "And I liked going back after we've gone through all the Power Points, and all the discussion, and all the working in our classrooms. Going back through and reading that article" (FI-PB-2).

The discussion in this section was generated from cross-case analysis of the experiences of seven secondary science teachers as they learned about the specialized features of science language. Factors from the three systems, the individual, the professional development, and the classroom, interacted to either facilitate or inhibit science teachers' learning process and integration of strategies into their instructional routines.

Opportunity to talk emerged as the core concept that accounted for the greatest influence on how science teachers learned about science language and how to implement strategies. The levels of teachers learning and integration were impacted by the interaction between the core concept, *opportunity to talk,* and other pertinent influences such as motivation to learn, prior knowledge, access to expert knowledge, and time.

Although the components in each system served to influence the science teachers' learning, there were variances between cases in the levels of learning and integration. In most cases, however, the interaction between the components of this model facilitated learning about the specialized features of science language. Subsequently, the science teachers' knowledge acquisition was in a state of continual refinement from the interaction between their opportunities to talk with components from the individual, the school context, and the professional development systems.

Science Teachers' Willingness to Learn

Secondary science teachers do want to understand how to provide reading instruction that helps students improve their understanding of scientific texts. The science teachers in this study were excited about learning about science language and willing to try new ideas to address reading in science in their classrooms. The findings from this study confirm previous studies that claim secondary content teachers want to understand how to address the reading needs of their secondary students (Siebert & Draper, 2008; Yore, 1991). The science teachers reported a desire to know how to help their students with reading in science. The findings show that that the science teachers were motivated to be a part of the study because they believed it was important for students to read in science.

The science teachers' willingness to learn was evidenced by their involvement in previous experiences with content area reading. The science teachers reported that they had attended previous workshops and meetings to learn about reading in content areas and had even read texts by popular literacy educators like Janet Allen and Chris Tovani. However, most of what they learned was generalized and the most the science teachers appeared to use in their classrooms from any of those workshops were vocabulary oriented strategies. Even though the science teachers came to this study feeling like they still did not have the tools they needed to successfully teach reading in science, they were enthusiastic about finding new ideas. This finding confirms Yore's (1991) report that science teachers want to help their students learn how to read science.

This study challenges previous studies that describe secondary content teachers as resistant to integrating literacy strategies into their classrooms (Alvermann & Moore, 1999; O'Brien, Stewart, Moje, 1995; Vigil & Dick, 1987). The science teachers in this study were not resistant, but eager to understand how they could integrate discipline-specific strategies into their instructional routines. Even when the study was closing the teachers were thinking about the possibilities of continuing in their learning about the specialized language of science. Lisa probed the other teachers to think about how to share information from the study with fellow teachers.

> I wanted to see if we could not get set up and we were talking about this as well and I know you're a very good writer as well, to get a grant to get her back. Here's my ah-ha fantasy moment; have you come back next year if you're in the area, work with the ninth grade science teachers especially.

> We can come in and work with them as the backup old veterans. I would be willing to sit down with Summer, with Paula and a bunch of you other guys and come up with some ideas so that when the ninth grade teachers come back we have packets ready for them here's something's that you can do. I would love to see us get a grant, have you come back, work with all the ninth grade science teachers. (PD8-3/10/09)

The science teachers in this study were willing to learn about strategies that helped them to teach about the specialized language of science and even showed interest in continuing to explore how to work collaboratively with other members in their department to disseminate the knowledge they had acquired. This lesson learned is promising for future work with secondary science teachers. This finding further supports recommendations that literacy educators reframe how they view the willingness of secondary teachers to learn about disciplinary literacy practices (Siebert & Draper, 2008; Shanahan & Shanahan, 2008).

Multiple Levels of Support for Integration

The science teachers needed support in order to successfully integrate new reading strategies into their teaching routines. Findings showed that certain aspects of the professional development program served to support the science teachers' learning of the specialized features of science language. First of all, the design of this professional development program planned for peer collaboration and conversation about pertinent topics related to teaching and the specialized language of science; qualities supported in literature about how to plan for effective professional development (Brownell et al., 2008; Feiman-Nemser, 2001; Richardson, 2003). Findings showed that the most powerful influence from the professional development system on the science teachers' learning and integration of strategies specific to science language was their opportunity to talk. To begin, the science teachers valued the time to listen to one another share ideas and reflections on what they were learning about the specialized language of science. The opportunity to talk during the professional development modules allowed the science teachers time to plan together and share stories about their classroom experiences with integration of ideas from the meetings. These findings mirror research that suggests teachers value time to talk about their learning and practice with one another and support recommendations from the literature that collective participation should be a component of meaningful professional development designs (Garet, Porter, Desimone, Birman and Yoon, 2001).

Opportunities to talk about practice fostered the confidence of the science teachers' to try ideas related to the teaching of the specialized language of science into their teaching routines. The science teachers reported that when they listened to their peers talk about how they applied a strategy into their teaching it gave them ideas about how they might adjust the strategy to fit into their own teaching. Having an opportunity to talk contributed to the teachers feeling comfortable to practice and experiment with new ideas which helped to build their confidence to try it out in their own classrooms. These findings support recommendations to create places where teachers feel safe to think about and try new practices in education (Darling-Hammond & McLaughlin, 1995; Desimone, Birman, & Yoon, 2001; Garet et al., 2001).

In addition to the support offered during the professional development meetings, the science teachers valued support from the facilitator. The science teachers liked that that I was available to come into the classroom to observe and sometimes participate in teaching the lessons. An important note here is that I was flexible in the level of support I offered to teachers. Whereas Brad and Bette liked me to come and do demonstration lessons in their classrooms, Lisa preferred that I observe her in a more traditional manner. Patsy on the other hand liked to consult with me during the lesson. She would lead the lesson and I would sit towards the back and watch, but she would often ask me to elaborate on how to use a particular strategy or she would even ask me what to so when she felt stuck. This study revealed that teachers had individual responses to the level of support they required or wanted while exploring the use of the new strategies into their teaching.

The lesson learned here is that when asking science teachers to integrate reading strategies into their teaching it is important to provide multiple levels of support. The design of the professional development modules built in peer and facilitator support. The science teachers were then able to access that support as desired. However, ensuring that the science teachers continue to use the strategies once the support structures are removed is challenging.

The multiple levels of support offered to the science teachers in this study show promise for positively impacting teachers' learning and continued integration of strategies. An email communication the following school year from a teacher in the study evidenced that she was continuing to use the ideas from the professional development program in her teaching.

> I shared how wonderful your work with us was last year with my administrator, Mr. Williams. We are again punching reading at school this year! I want to let you know that I started the year off with a different approach to vocab – thanks to your suggestions and our class. When I brought up the topic of vocab, the whole class inwardly and one or two outwardly groaned – ugh! But then I shared the Word Questioning ideas and the logographs and they rejoiced!!! I am including focusing on the LANGUAGE of science right from day one with them, and they are encouraged now that they already do some of the morphemic analysis

techniques and are positive about adding some others to their bag of tricks! (EC-PB-9/23/09)

Curriculum Negotiation

The science teachers sometimes struggled to find ways to integrate what they were learning with the curriculum they were using. Even though their understanding was developing about how science language was complex, thinking about how language played a role in what they were teaching provided a new set of challenges in planning for implementation. In this instance, teachers' required more support through means such as coaching, follow-up sessions, and feedback to reflect on practice, actions that are supported in current literature about effective professional development (Darling-Hammond & McLaughlin, 1995; Guskey, 2002).

The science teachers valued individual meetings with the facilitator. For instance, Billie was planning her lessons on density, she and I met to look through her upcoming chapter to find examples of density in her textbook. In the same manner, Brad and I met one day to look at his chapter on arthropods to find examples of abstraction. Bette and I also met in her room to preview a passage she was going to use with her students to teach about abstraction. We read through line by line, identifying instances when the author used abstraction. These meetings were critical to helping the teachers see examples of the features of science language in their textbooks.

It is important when planning for implementation of these new strategies to take time to help the teachers link ideas from the professional development to their existing curriculums. This is another example of how the teachers need planned time to meet with the facilitator and one another to peruse their curriculum and plan specific lessons to take into their classrooms. The teachers noted that one of the areas they would have liked to extend in the professional development effort was the time for lesson planning. Teachers need structured time to plan lessons with the support of their fellow teachers and the facilitator in order to make appropriate connections between the new ideas and their existing curriculums.

Another issue in relation to lesson planning was the availability of alternative resources for reading. The main source of reading in these classrooms was the science textbook or FCAT practice books. Alternative reading sources were not readily available. Taking in examples of alternative texts that matched teachers' curriculums would be useful in helping teachers see how they can bring in other reading sources to help them meet the objectives of their curriculums.

Facilitator Knowledge and Action

In discussing the impact of the facilitator it is also important to consider how the knowledge level of the facilitator could inhibit growth in teacher learning. It has come into question how much knowledge literacy educators have to provide effective training in reading across content areas (Moje, 2008; Siebert & Draper, 2008). In this case, this was the first time I had presented this type of information to science teachers in an extended professional development setting. In reflection on transcripts and lessons, it became evident to me that there were places where I could have clarified understanding. For example, when the teachers struggled with understanding the concept of abstraction, I should have supplied more opportunities to read and analyze sample texts for abstract nouns. The strategies that I modeled in the class did not provide enough experience for the teachers to think past the process of nominalization. Because of my inexperience with teaching about the specialized language of science, I did not see right away where they were struggling. I needed to place more emphasis on showing the teachers how the features of science language not only functioned but also how they were necessary to make science what it is.

In order to counter my lack of experience in teaching science however, I presented myself as the literacy person and acknowledged early on in the study that the teachers were the experts in science. I continued throughout the study to emphasize that they were the science experts and I was looking to them to tell me about the efficacy of these ideas. The following quote from our final meeting illustrates this point.

> Because one of the things I'm really just looking for is how does this start to fit into your daily lives and your daily teaching? Is it relevant or not, should we bother? I'm coming to you guys because you guys are the real deal. You're the ones that teach the kids so it's your voices that matter to me. (PD8-3/10/09-20)

The science teachers expressed appreciation that I valued and prioritized their expertise in science. For example, Lisa expressed her opinion in the final interview: "I thought it was indescribably sweet when you said that you didn't know the science that well but you certainly know you're educational procedures and how to get the best out of all of us" (FI-VL-8).

Conditions of Professional Development

One condition of the professional development modules that motivated the teachers to learn was that the information was content-specific. The science teachers in this study valued the discipline-focused information provided in this professional development program. They often reported the benefits of being able to focus on how the information presented pertained only to science. This finding reflects recommendations that professional development for secondary teachers should be centered around particular content areas (Garet, Porter, Desimone, Birman and Yoon, 2001; Moje, 2008; Rosebery et al., 1996). It is also reflects the findings from other studies that report positive results when professional development in content literacy was focused on just one content area (Glasson & Lalik, 1993; Fang et al., 2007).

Another condition of the professional development that was influential was that the teachers were working together from the same school and the same content area to develop their knowledge and understanding. Cochran-Smith & Lytle's (1999) concept of knowledge-of-practice supports this kind of learning environment. In this study, the science teachers' acquisition of knowledge was not just focused on improving their techniques of teaching reading in science, but also on nurturing their understanding. This blend of understanding and application embodies the knowledge-of-practice paradigm which values teachers working together in a specific location to think about and question practice and take it into their classrooms (Bondy & Brownell, 2004).

In addition, professional development that is highly focused on helping teachers prepare directly to make an impact on their practice has been shown to be valued (Garet et al., 2001). The teachers in this study valued the information they were learning because they believed it would impact their teaching practice. The focus during the professional development modules on how to take the ideas into the classroom was perceived by the teachers as useful. The science teachers reported that having the time to plan how to implement the ideas was important to them. Even though the time for planning was limited, the teachers felt it was necessary and indicted that more time for planning for how to take the ideas into the classroom would be helpful.

Another aspect of the professional development that received attention in the findings was the access teachers had to professional literature about the specialized language of science. The science teachers reported that having access to expert knowledge in the forms of texts and articles influenced their buy-in to the ideas as viable. Because the ideas presented to them about science language were backed by research in the field, the science teachers were more easily convinced that language served an important role in shaping knowledge in science. Research upholds this idea that providing teachers with access to professional literature helps to clarify the need and purpose for implementing the ideas from the workshops (Watson & Manning, 2008).

Influence of the School Culture

The school climate served an important role in the success of this study. The teachers were part of a school where learning was valued as evidenced by the small learning communities already present. In addition, the principal showed her support for the project by visiting the science teacher meeting and encouraging the teachers to participate in the study. The impact of school climate on the success of secondary teachers implementing reading strategies has been a source of concern (O'Brien, Stewart, Moje,1995). The Reading Next Report (2004) states one of the 15 conditions necessary for success is administrative support and school climate (Biancarosa & Snow, 2004).

In addition to the school climate, the classroom climate also served a role in facilitating the teachers' learning. There were indications in the findings that the science teachers' belief in the usefulness of the strategies was related to their perceptions of how they saw the ideas impact student learning. The science teachers reported that when students were successful with a strategy it helped the teachers to see how a focus on language in science could support the students' in the learning of science content. Fang et al. (2008) found similar results in their work with two middle school science teachers. Guskey's (2002) model of teacher change claims student outcomes as the most powerful influence. This study lends evidence to the possibility of this model being true.

Time

Research indicates that giving teachers time to plan and reflect on their practice is an important component of effective professional development experiences (Darling-Hammond, 1995; Fieman-Nemser, 2001; Garet et al., 200). In this study, time served to both facilitate and inhibit the teachers' learning process. For example, Billie indicated that if she had greater opportunities to practice in the classroom it would help her to continue using it in her teaching.

> Like, more practice incorporating it into lessons. You know, even though we did have, like, a whole month from each to the next, it seemed like it was so short. You know, it was still in my mind- I knew how to do it, but I didn't keep doing it because we moved to a new topic. . . and next year would be better, because I can build it into the lessons and be more prepared to kind of build upon it as the year goes on. So I don't think – I think time was a factor. (FI-JTB-9, 2)

Bette also commented about time. She wanted more time for feedback and support in implementing the lessons. She said,

> I guess I wish I was able to make more time to, I guess, implement the lessons or maybe have another teacher watch me do a lesson or maybe, during my planning, I could watch them do it. So I could see it more instead of just doing it once and saying, "Okay, great. We did it." (FI-JB-9)

The science teachers also addressed time as a factor in opportunities to talk. Often during the professional development meetings we had to stop talking about something in order to move on. For example, in our session where teachers shared their experiences teaching lessons about density, I had to stop the discussion to move on to learning about the new topic of genres (PD-02). Lisa described the problem when she said, “Sometimes we just wanted to go on and on and on and we had to get on to the next thing and we were all kind of a little bit “Uh OK” (FI-VL-8). Casey also addressed the issue of running out of time during the professional development meetings, when she said, “But we just kinda, sometimes, would run out of time. I think that I would have been willing to stay that other hour to start actually working more on it and getting some ideas from you” (FI-MC-4).

Providing the appropriate amount of time for teachers to learn and integrate ideas into their teaching is a challenge. In this study, the science teachers felt that more time would have helped them to feel more successful in their planning and integration.

Limitations

As addressed in Chapter 1, there are limitations to the generalizability of the findings of this study. For example, the number of the teachers and the context both limited this study. First of all, the number of teachers was small. Only seven teachers participated in the professional development modules. In addition, the seven teachers were selected based on their willingness to participate. Had the professional development been required, findings may have shifted. Also, the context of this study was limited. This study took place in one school in one county, therefore, different results might be yielded in a school with challenges to the school climate or a different student-body makeup.

In addition, the length of the study was limiting. The study happened during a 7-month period during a school year. Perhaps following the teachers into another year to provide more support would enhance the findings from this study. It is unclear if or how much the teachers are still using the methods learned in the professional development sessions.

Finally, this study only looked at the learning of secondary science teachers. It is difficult to generalize that the same conditions would support the learning of other content-area teachers. However, these findings do offer promising practices for future research.

Implications

Findings from this study support the need for further exploration into how to help secondary science teachers learn about the language demands of science text. There are indications from this study that secondary science teachers' learning is anchored in their prior knowledge and experience in teaching the technical words that are specific to science. However, findings from this study also indicate that providing science teachers with opportunities to learn about the specialized features of science language and integrate those ideas into their teaching is a promising practice. Specific features of the professional development experience served to support science teachers' learning and offer insight into future planning of professional development for science teachers. It is also believed that findings from this study can extend across the disciplines and impact future practices and research in adolescent literacy.

Need to Foreground the Role of Language in Science Teaching and Learning

This study looked directly at how secondary science teachers' understanding of the specialized features of science language developed over the course of a 7-month professional development study. The influence of opportunities to talk about their learning held the most value to these science teachers. This suggests that future practice in providing professional development for content teachers in reading provide ample time for teachers to share and discuss the ideas they are learning and the strategies they are implementing in their classrooms.

The science teachers in this study were convinced of the efficacy of ideas when other teachers attested to their success in the classroom or articulated their understanding of a particular concept. The peer interactions served as a powerful influence on the development of teachers' understanding and the change in their dispositions about science and reading. This informs our understanding of the importance of providing opportunities for teachers to talk to one another about disciplinary literacy and classroom practices that are useful.

In addition to opportunities to talk to one another, findings indicated that the teachers valued support and feedback from talking to the facilitator. By participating in the classroom, presenting materials, and monitoring the discussions during professional development meetings, the facilitator became an important influence on the teachers' growth in understanding about the specialized language of science. The science teachers in this study depended on insight from the facilitator on implementation of strategies and student learning processes. This finding suggests that secondary content teachers need continual support and encouragement as they engage in learning about new ways to address literacy in their content areas.

In addition, this study showed that science teachers believe that vocabulary is important in teaching reading to secondary students. During this study, the science teachers continued to address technicality in reading and were less comfortable with abstraction, density, and genres. When designing professional development to teach about the specialized language of science it is important to give science teachers many opportunities to compare their new learning to what they believe about reading in science and provide support for their understanding about the less familiar components of the specialized language of science.

Need to Equip Teachers with Knowledge of Grammar and its Function in Science Meaning Making

In this study the teachers' lack of grammar knowledge influenced their understanding and integration of discipline-specific reading strategies in science. When working with science teachers it is important to provide time to learn about and practice identifying the grammatical features of science language. For example, in this study teachers felt uncomfortable with their knowledge level of embedded and non-embedded clauses when studying density. More practice during the professional development analyzing sample texts and identifying grammatical construct could have helped to alleviate this problem. When designing professional development for science teachers about disciplinary-reading practices, it is important to include explicit instruction and sufficient practice in looking at science texts for how the grammar is used to develop meaning.

Encourage Border Crossing between Reading and Science Educators

The focus on science language in this study honored the unique challenges that science texts present to both the teaching and learning of science. The science teachers valued the discipline focused content of the professional development sessions and felt that the strategies presented addressed their needs in helping students in reading scientific texts. The science teachers in this study attested to the usefulness in understanding how language functioned in science in order to better teach reading in science.

It is important to for literacy educators and science educators to collaborate in order to better understand how literacy and science work together. Siebert & Draper (2008) suggest that there will be little impact on changing secondary content teachers' attention to literacy if messages to them do not include specific attention to the way that literacy is used with those disciplines. This study confirms that these science teachers were appreciative and responsive to learning about literacy in science. These findings support continued efforts in identifying ways to support secondary teachers' in their learning about how language works in particular disciplines to create knowledge.

School Structures and Personnel That Support Innovation

The need for supportive leadership at the secondary level is identified as a key component of successful secondary literacy programs in The Reading Next Report (2004). The findings from this study confirm the recommendations of that report. The support of the principal was highly valued by the science teachers. She encouraged teachers to participate in the study and supported them by visiting their classrooms and asking them about the study. In addition, the reading specialist was also supportive of the science teachers and even attended one meeting to learn more about what the teachers were doing in the study.

Despite the support from the principal and reading specialist however, neither one had the knowledge level to support the teachers' learning. The principal was a prior health teacher and the reading specialist was not familiar with disciplinary-reading practices. Implications from this research show that support is important from leadership, but could be enhanced with personnel in the building who can support the teachers' classroom practices. The science teachers' were dependent on the support of the facilitator whose position was temporary. Secondary schools need personnel in the building who can support content-teachers use of disciplinary-reading practices.

In addition, teachers need school structures that support their implementation of new ideas. The science teachers indicted that if they had common planning times or more time with their students they could more fully address the concepts from the professional development modules. In order to address the needs of the teachers, secondary schools should consider ways to include flexible scheduling or longer class periods to support teachers in implementing disciplinary literacy practices into their teaching.

Another factor that provided challenges to the teachers was a lack of a variety of science texts in the classroom. Science teachers need access to various resources such as science magazines for kids and appropriate research articles to give students a wide variety of reading experiences in science. School libraries could support science teachers in this area by including a multiple types of scientific texts in their collections that support the teachers' curriculum. Science teachers and librarians could work together to identify appropriate and useful materials.

Create Communities of Practice That Value Language in Schooling.

It is important to develop communities of practice in secondary schools that allow teachers to meet together in discipline related teams to think about how language functions to create meaning in that subject area. The science teachers in this study valued time to work together and discuss how language played a role in learning about science. In this case, the science teachers met to look closely at science texts and consider how to help students understand the language. In addition, the teachers shared their struggles and successes in implementing ideas associated with science language. This was helpful because it developed a support network for the teachers to share ideas and encourage one another to continue to implement strategies. For example, if one teacher struggled with implementation and reported it to the group, another teacher would offer insight into another way to try the idea. The science teachers reported that knowing how other teachers' were planning for their lessons and how the integration process happened was useful. Previous experiences with learning about reading in the content area had required the teachers to try the ideas independently in their classrooms and the teachers reported often abandoning the idea if it was not easy to implement. Creating a place where teachers could collaborate with one another proved to make an impact on the science teachers' use of ideas from the professional development modules. Developing communities of practice that value language in schools can support teachers in learning how to better help their students learn how to improve reading in particular content areas.

Future Research

Although this study supports the value in providing secondary content teachers with information on how literacy is used within their discipline, much research is still needed. In considering the demands of advanced literacy instruction, it is important that literacy experts and content area specialists understand how literacy is used in particular disciplines. In science, scholars describe the unique ways that language functions to create theories and ideas (Veel, 1997; Halliday & Martin, 1993), and have recommended strategies to address issues of language in science in the classroom (Fang, 2006; Fang & Schleppegrell, 2008), yet more information is needed on how these ideas actually take shape in the classrooms. Future studies need to consider how these ideas impact student performance. Experimental studies are needed to examine the impact of language-based teaching practices on student learning. Further, comparison studies examining the effects on student science-learning of different approaches to reading integration (e.g., disciplinary-specific reading strategies vs. generalized reading strategies) could inform our understanding of the impact of disciplinary reading strategies.

Another area in need of investigation is the knowledge level of the facilitator. This study reflects claims that characteristics and knowledge of the facilitator can make an impact on teacher learning (Fieman-Nemser, 2001; Siebert & Draper, 2008). Literacy experts typically are not specialists in content areas, yet they are responsible for delivering content literacy training and professional development to content teachers. At this point, the question still remains about how literacy educators can develop enough expertise across the disciplines to administer effective professional development to content area teachers.

Future research also needs to consider the importance of time and support on content teachers' learning and application of disciplinary literacy practices. The science teachers in this study indicated a desire to continue working together to develop their understanding of how to implement the ideas associated with the specialized language of science into their classrooms. Ethnographic studies investigating ways to most effectively help teachers learn and teach the language of science could be helpful.

Further questions remain about how the teachers' experiences and the culture of secondary schools can facilitate content teachers working together to support their learning about best practices in addressing literacy in the disciplines. Qualitative studies investigating how science teachers' background/experience and school culture impact their adoption of disciplinary-specific language/literacy practices could contribute to our knowledge in this area.

Finally, similar types of studies need to investigate the learning processes of teachers in other content areas. It is important to also understand how teachers learn about the function of language in subjects such as history, math, and art. This could give us greater insight into the usefulness of approaches to disciplinary literacy which include a focus on the linguistic aspects of particular texts.

Conclusion

It is believed that teaching adolescents to understand how language is used in particular ways in content area like science and math will further improve their understanding of texts in those disciplines. Therefore, it becomes necessary to work with content teachers to help them understand the role of discipline-specific reading in their areas. Designing effective professional development efforts in disciplinary literacy however is a challenge.

In science, language plays a role in shaping knowledge. Fang & Schleppegrell (2008) offer the approach of functional language analysis to help science teachers understand how to teach their students to read science. Fang (2008) argues that reading instruction in secondary science classrooms should incorporate strategies to address the specialized features of science language. Because science texts are the primary medium through which science knowledge is shared, it is important that students understand how to read these texts. Only through an understanding of the complex nature of science language, Fang argues, can students begin to meet the language demands of these difficult science texts.

In order for the students to develop an understanding of the language of science, their science teachers must understand how language serves to shape the theories and ideas in science texts. For this reason, it is important that secondary science teachers have time and opportunities to explore the role that language plays in constructing science knowledge and how that knowledge translates into classroom practice. This study showed that when teachers had time to talk about their learning, they were motivated to try new ideas.

Engaging in meaningful professional development can support science teachers' learning about disciplinary literacy practices that support student learning. As secondary science teachers are afforded opportunities to talk about their learning and teaching of the way that language functions in disciplines, changes in dispositions and practice can occur.

This research shows the potential for meaningful professional development to impact how teachers think about and teach reading in secondary content areas. Crossing borders between literacy and science will enhance science teachers' instructional routines and in turn, hopefully impact student learning. While the relationship between literacy and science is complex, this study confirms that it is worth investigating how literacy educators and science experts can work together to improve the teaching and learning of science. Improving reading instruction in science and other disciplines will provide our adolescents with the ability to engage as critical and productive citizens in a world that demands higher levels of literacy to lead productive and enriched lives.

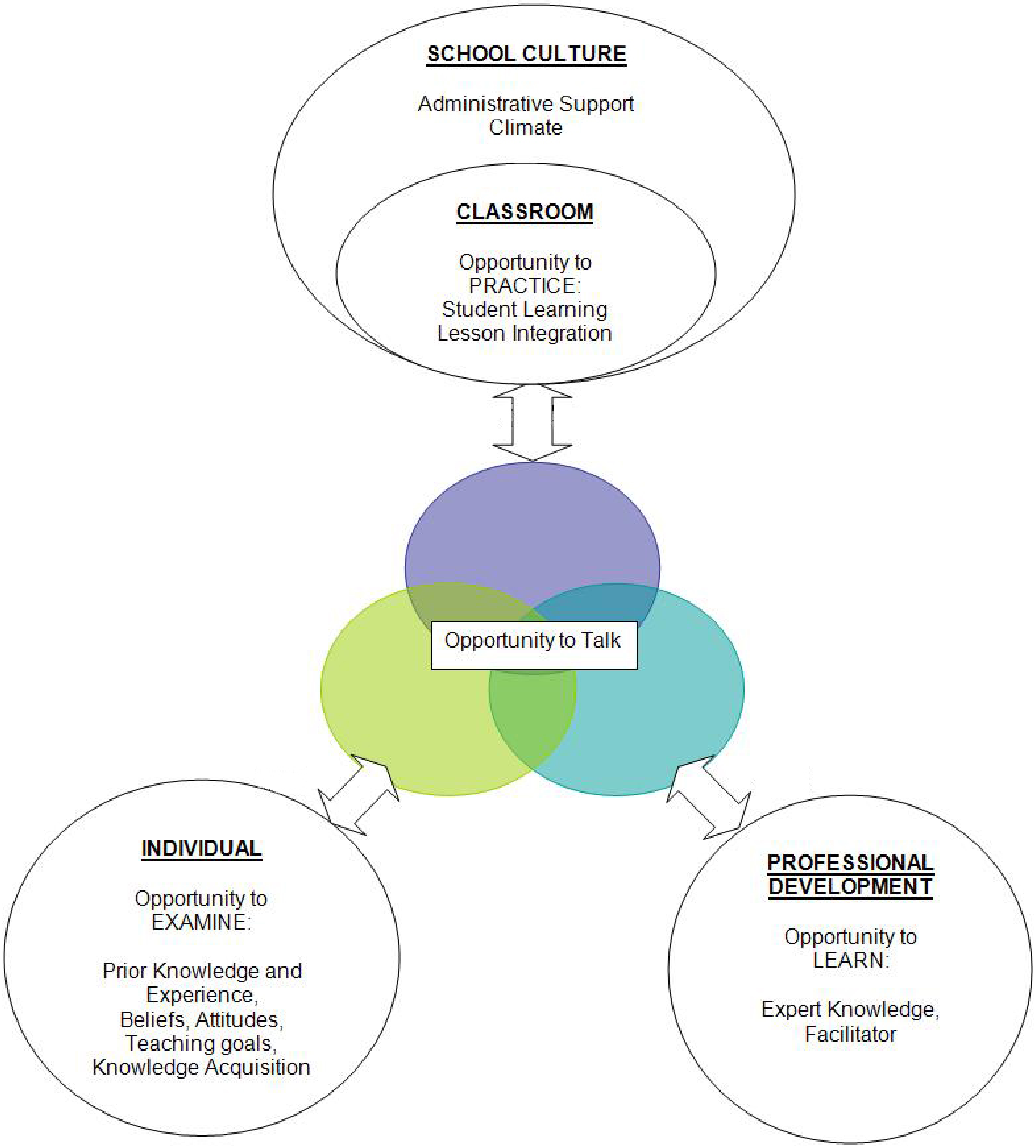

Figure 7-1. Grounded Theory Diagram

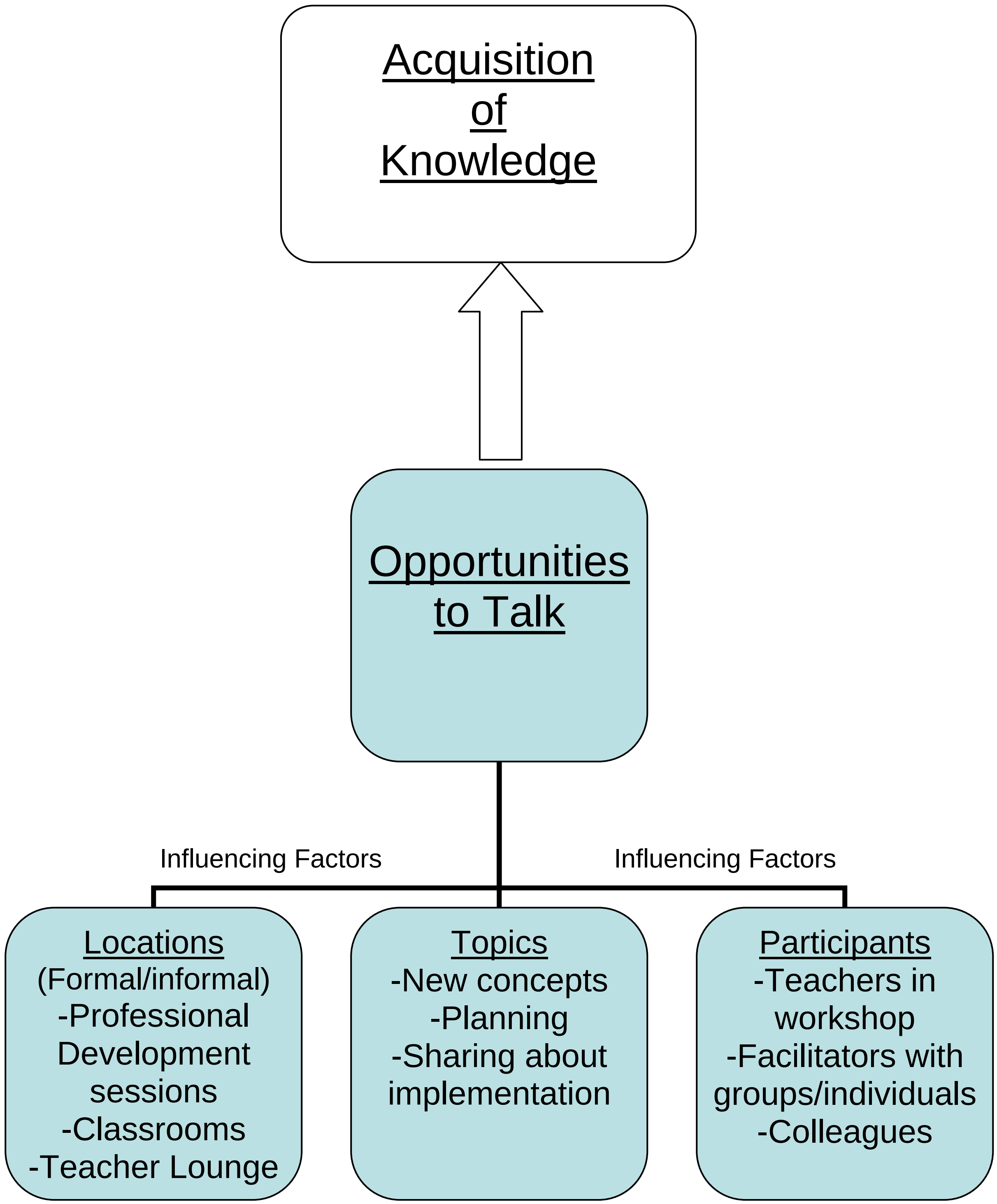

Figure 7-2. Model of Opportunities to Talk

APPENDIX A
INFORMED CONSENT FORM

Protocol Title:

Secondary Science Teachers Learning to Teach Science as Specialized Discourse: A multi-case study

Please read this consent document carefully before you decide to participate in this study.

Purpose of the research study:

The purpose of this study is to understand how science teachers learn and teach about the specialized discourse of science.

What you will be asked to do in the study:

In this study you will be asked to participate in 7 two-hour meetings with the researcher. During these meetings you will be asked to participate in readings and discussions about science literacy. You will also be asked to bring classroom materials to the sessions to review with your peers. Meetings will be either audio or video taped.

In addition, you will be asked to complete an initial survey about your previous experiences with reading and science. You will also be asked to participate in 2 interviews regarding your participation in this study at your convenience.

Finally, you will be asked to allow the researcher to observe in your classroom for up to one class period per week during the time of the study.

Time required:

Dates: August 2008- May 2008

Meetings to be held tri-weekly between August and February.

Data analysis and final interviews held between March and May.

Approximate hourly commitment:

15-17 total hours.

Risks and Benefits:

None.

Compensation:

You will be paid $300.00 compensation for participating in this research.

Results Distribution:

Results of this study may be presented at conferences or published in educational journals.

Confidentiality:

Your identity will be kept confidential to the extent provided by law. Your information will be assigned a pseudonym. The list connecting your name to this number will be kept in a locked file in my faculty supervisor's office. All data including video and audio tapes will be accessible to the researcher and the faculty advisor.

When the study is completed and the data have been analyzed, the list will be destroyed. Your name will not be used in any report. All audio and/or video recordings will be destroyed once analysis is completed.

Voluntary participation:

Your participation in this study is completely voluntary. There is no penalty for not participating.

Right to withdraw from the study:

You have the right to withdraw from the study at anytime without consequence.

Whom to contact if you have questions about the study:

Primary Contact: Jennifer Drake Patrick, Graduate Student, College of Education, School of Teaching and Learning, 2417 Norman Hall, phone 352-392-9191 or 757-871-8823(cell). jdrakepatrick@aol.com

Faculty Advisor: Dr. Zhihui Fang, PhD, College of Education, School of Teaching and Learning, 2417 Norman Hall, 352-392-9191 X 287.

Whom to contact about your rights as a research participant in the study:

IRB02 Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; phone 352-392-0433.

Agreement:

I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Participant: ____

Date: __________________

Principal Investigator: ______________________________________

Date: __________________

APPENDIX B
PERSONAL STATEMENT

Teaching History:

Number of years teaching: ___________________________

Degree(s) earned: ____

Type of teaching program: 4 yr. traditional alternative

Other relevant job experience: ________________________________

Current Position at OPHS:

Room Number: ___________

School email address: ____

Courses taught: (please include grade level)

Period 1: ____

Period 2: ____

Period 3: ____

Period 4: ____

Period 5: ____

Period 6: ____

Period 7: ____

What time is your lunch period? ________________________________

Thank you for taking your time in answering the following questions. Please provide detailed answers, using specific examples and references when you can.

1. What role, if any, has reading played in your personal endeavor to learn about science? Please explain

2. What role, if any, does reading play in learning about science? Please explain your answer.

3 a. What are some similarities between reading in science and reading in other subject areas such as….?

b. What are some differences between reading in science and reading in other subject areas such as..?

4. What reading skills do students need to access scientific texts successfully?

5. What issues do your students confront in accessing scientific texts? And how do you address these issues in your teaching?

6. What would you hope to learn in this professional development effort about helping students with science texts?

7. Tell me about the reading materials available to use in your classroom.

Draw a semantic map representing the skills you believe students need to read scientific texts. Give a complete description and justify your map.

APPENDIX C
MIDTERM INTERVIEW QUESTIONS

Mid-Term Interview Questions

What made you pursue a career in teaching?

What constitutes good practice in science teaching? What should a teacher know how to do?

What experiences best prepared you for being a science teacher?

How would you characterize your own content knowledge in science?

What is the role of language in learning and teaching science?

How is science language technical? Abstract?

Tell me about using the strategies for technicality in your classroom?

Which ones did you find the most useful/not?

Tell me about using the strategies for abstractness in your classroom?

Which ones did you find the most useful/not?

What are you thinking about your science teaching as a result of participating in this workshop?

Please share any questions you may have about the material up to this point.

APPENDIX D
EXIT INTERVIEW PROTOCOL

Time of interview:

Date:

Interviewee:

Questions:

1. Tell me how science language is different from the language we use in our everyday life.

2. On a scale of 1 to 5 with 5 being the highest, how would you rate your understanding of each of the following topics we covered on scientific language?

Technicality

Abstractness

Density

Genres

3. Explain your rating of . . .

Technicality

Abstractness

Density

Genres

4. Do you view science reading differently than you did 6 months ago?

5. What new understanding have you developed about science text, science reading, and the teaching of science reading in your class?

6. How are the teaching tools you learned here different from the ones you were taught before?

7. Are there any challenges in implementing what you learned from these professional development workshops? Could you describe them?

8. What did we do during the past 6 months that may have facilitated your learning about science language?

9. How has this professional development had an impact on you?

APPENDIX E
OBSERVATION PROTOCOL

Classroom Observation

Teacher: ________________________ Class: _________________________

Date: ______________ Time: (b) _______ (e) _________ Total minutes:______

Descriptive Notes	**Reflective Notes**

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BIOGRAPHICAL SKETCH

Jennifer Drake Patrick completed her undergraduate degree in communications education at Miami University in 1992. She received her master's degree in reading education in 1993 from Miami University. She taught middle school reading in Worthington, Ohio from 1993-1995. From 1995-1998 she taught high school in the Jacksonville, Florida area. Jennifer worked for The Johns Hopkins University as a mentor-liaison with The Center for Reading Excellence from 1999-2002. While there, she also taught reading courses in the graduate school of education. Jennifer has presented at various national conferences including the National Reading Conference (NRC) and The National Council of Teachers of English (NCTE). She has published in *The International Journal of Science* and *Language Arts*. Jennifer received her doctorate from the University of Florida in 2008 with a focus on Reading Education. Jennifer's research interests include secondary content reading and professional development. Jennifer, and her husband, Rob, currently reside in Fleming Island, FL and have three children, Maggie, Trey, and Makayla.