ADDRESSING SCIENTIFIC LITERACY THROUGH CONTENT AREA READING AND PROCESSES OF SCIENTIFIC INQUIRY: WHAT TEACHERS REPORT

by

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ABSTRACT

The purpose of this study was to interpret the experiences of secondary science teachers in Florida as they address the scientific literacy of their students through teaching content reading strategies and student inquiry skills. Knowledge of the successful integration of content reading and inquiry skills by experienced classroom teachers would be useful to many educators as they plan instruction to achieve challenging state and national standards for reading as well as science.

The problem was investigated using grounded theory methodology. Open-ended questions were asked in three focus groups and six individual interviews that included teachers from various Florida school districts. The constant comparative approach was used to analyze the data. Initial codes were collapsed into categories to determine the conceptual relationships among the data. From this, the five core categories were determined to be *Influencers*, *Issues*, *Perceptions*, *Class Routines*, and *Future Needs*. These relate to the central phenomenon, *Instructional Modifications*, because teachers often described pragmatic and philosophical changes in their teaching as they deliberated to meet state standards in both reading and science.

Although Florida's secondary science teachers have been asked to incorporate content reading strategies into their science instruction for the past several years, there was limited evidence of using these strategies to further student understanding of scientific processes. Most teachers saw little connection between reading and inquiry, other than the fact that students must know how to read to follow directions in the lab.

Scientific literacy, when it was addressed by teachers, was approached mainly through class discussions, not reading. Teachers realized that students cannot learn secondary science content unless they read science text with comprehension; therefore the focus of reading instruction was on learning science content, not scientific literacy or student inquiry. Most of the teachers were actively looking for reading materials and strategies to facilitate student understanding of science concepts, but they did not want to give up limited class time attempting methods that have not been proven to be successful in science classrooms.

This dissertation is dedicated to my family for their confidence, support, and love.

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LIST OF ACRONYMS

ACS	American Chemical Society
AR	Accelerated Reader
CRISS	Creating Independence Through Student-owned Strategies
ESOL	English as a Second Language
FAST	Florida Association of Science Teachers
FCAT	Florida Comprehensive Assessment Test
IRA	International Reading Association
MCREL	Mid-Continent Regional Educational Laboratory
NAEP	National Assessment of Educational Progress
NCLB	No Child Left Behind
NRC	National Research Council
NRP	National Reading Panel
NSES	National Science Education Standards
NSTA	National Science Teachers Association
SSS	Sunshine State Standards

CHAPTER ONE: INTRODUCTION

Secondary science teachers today are faced with the dilemma of teaching science content reading skills while incorporating the processes of science into their instruction. During the 1990s, *Science for All Americans* (Rutherford and Ahlgren, 1990), the *National Science Education Standards* (*NSES*) (National Research Council [NRC], 1996), and Florida's Sunshine State Standards in Science (Florida Department of Education, n.d.) were published. These documents emphasized that students should learn both the content and processes of science to become successful citizens in our society. During the same time, there has been a nationwide effort to help all content-area teachers, including science teachers, integrate reading instruction into their curricula (Holliday, Yore, & Alvermann, 1994), and many secondary science teachers have been strongly encouraged to attend inservice workshops or other professional development activities to learn content reading strategies to help their students become better readers. We know that teachers can help their students learn science through teaching content reading strategies, but I wanted to know how teachers are infusing reading into their inquiry science classrooms. This study investigated how secondary science teachers have addressed the problem of teaching science processes, student inquiry skills, and content as well as content reading skills in their classrooms during the eight years since adoption of national and state science standards.

Background and Significance

During my 30-year career as a secondary science teacher in Florida, I have witnessed and helped put into practice many innovations in science instruction. In the 1980s when I worked on the original draft of the Florida Sunshine State Standards for science, I was hopeful that teachers would use the standards as a blueprint for improved instruction. As science department chair, district science leader, National Board Certified teacher, and conference presenter, I have encouraged science teachers to modify their practice to include more active learning opportunities for students, including guidance for student inquiry and use of appropriate reading strategies. This research grew out of my belief that some science teachers have developed exemplary approaches to science inquiry combined with reading instruction that could be shared to improve science education in Florida.

Before implementation of national and state science standards, most secondary science teachers taught as they were taught, covering content that they or the district office deemed important. The emphasis of science instruction was to help students acquire a fundamental knowledge base, with the belief that understanding would come later (DeBoer, 1991; Gallagher, 2000; Phelps & Lee, 2003; Wasley, Donmoyer, & Maxwell, 1995). The amount of time spent on learning content through scientific reading and process-oriented laboratory work varied with the teacher. A few teachers opted to emphasize inquiry skills and a "hands-on" approach that would actively engage students, assuming that students could read their textbooks and other print materials for further explanations. Many teachers lectured and gave their students extensive notes or summaries of science content that was in the textbook because the teachers believed that their students would not or could not read on their own (Tobin, Tippins, & Gallard, 1994). The students in these traditional classes may have performed assigned labs where the procedure was written for them in recipe style, answers were known in advance, and the results were recorded in data tables or handouts prepared by the teacher or textbook company.

Presently, many secondary science teachers are unsure of how to proceed with the goal of producing scientifically literate citizens who understand the “big ideas” in science and how to relate these ideas to societal and personal issues (Tobin et al., 1994). Adoption of national and state science standards meant that teachers have had to decide how to address all aspects of scientific literacy, including content knowledge as well as development of process and inquiry skills. The science standards are unique in that they emphasize processes, inquiry, and attitudes, in addition to content. In 1990, Duschl claimed that most contemporary science education is focused on the process of justifying knowledge (what we know), but what is missing is the process of discovering knowledge (how we know). What we know is contained in comprehensive textbooks that require good reading skills for understanding, but how we know is learned through active participation in inquiry. In order to meet the national and state science standards that were developed in the 1990s, teachers must address content knowledge gained by reading as well as processes of scientific inquiry (NRC, 1996).

At conferences and meetings around Florida, I heard from many secondary science teachers who were instructed by their administrators to teach reading skills in science in order to raise reading scores on high-stakes tests, thus limiting the time spent in learning science process skills. That led to concern that some teachers omitted most laboratory work completely, stressing content area reading instead because of their realization that many students have problems understanding informational text. The problem of poor reading comprehension was exacerbated by the emphasis in elementary schools on literary text, mostly fiction stories, almost to the exclusion of nonfiction informational text, even though many students prefer “true” stories about real-world topics that interest them (Wilhelm, Baker & Dube, 2001).

Today, the vision of most educators, scientists, and policymakers is that science should be interesting and accessible to all students (Rutherford & Ahlgren, 1990). Secondary science teachers must make decisions about how to implement standards-based instruction so that students become the scientifically literate, independent learners envisioned in *Science for All Americans* (Rutherford & Ahlgren, 1990) and the *National Science Education Standards* (NRC, 1996). The recommendations for scientific literacy found in *Science for All Americans* (Rutherford & Ahlgren, 1990) include:

1. Being familiar with the natural world and recognizing its diversity and its unity
2. Understanding concepts and principles of science
3. Being aware of some of the ways in which science, mathematics, and technology depend upon one another
4. Knowing that science, mathematics, and technology are human enterprises and knowing about their strengths and limitations
5. Developing a capacity for scientific ways of thinking
6. Using scientific knowledge and ways of thinking for individuals and social purposes. (p. xvii)

Although these recommendations emphasize concepts and processes of science, not content, some of them could be met through content area reading about contemporary science issues. Student inquiry combined with content reading strategies would provide deeper understanding of the nature of scientific evidence and the importance of science in our everyday lives.

At the same time that secondary science teachers have been under pressure to teach the national and state science standards, they were faced with demands to include more reading activities in their curricula so that students could pass high-stakes reading comprehension tests mandated by federal legislation (No Child Left Behind, 2001). So far, the emphasis in reading at the national and state level has been on students becoming proficient in decoding skills and fluency by the end of the third grade, without much regard for making meaning of text (Stevens, 2003). This leaves teachers of grades 4 and above with the task of helping students progress from simply reading the words to reading for comprehension, which is needed to learn all subjects. Allington (2002) notes that although American students are second in reading in early grades, they fall to last place compared to other industrialized countries by the end of high school. He argues that this declining reading achievement is probably due to the failure to support student reading past elementary school and the fact that if students can decode words, they are not provided assistance in making meaning of different kinds of text. There has been a similar drop in science achievement, according to the No Child Left Behind web site (*The facts about…science achievement*, no date), with twelfth graders performing poorly on the National Assessment of Educational Progress (NAEP) in science and the Third

International Mathematics and Science Study, where U. S. fourth graders were ranked second but U. S. twelfth graders ranked 16th out of 20 countries.

With high-stakes science tests looming on the horizon by 2007 (No Child Left Behind, 2001), secondary science teachers have expressed great concern about meeting the science standards because the emphasis on reading, writing, and mathematics in elementary schools has meant that often science instruction was marginalized or even omitted in early grades. Reading and science have been treated separately in the secondary curriculum for many years, but there is growing evidence that teaching reading in all content areas will greatly improve our students' ability to learn on their own. Wilhelm et al. (2001. p. xviii) claim that "Reading is perhaps *the* foundational educational competence, and the electronic age has made this even more rather than less true." Wade and Moje (2000) further argue that we must view all kinds of texts as tools for learning and knowledge construction, including electronic texts, visual and auditory media, and student presentations. Most secondary science teachers have strong ties to their content area, but not much experience or training in teaching reading and how to use a variety of texts (Alvermann & Moore, 1996; Bintz, 1997).

The thrust of Reading First, a federal program that is part of No Child Left Behind legislation, is that all children who have the reading skills of phonemic awareness, phonics, fluency, vocabulary, and comprehension at the end of third grade will be successful in school (*Questions and answers on No Child Left Behind—Reading*, no date). As a result of this legislation, in February 2003, federal grants were awarded to school districts and educational consortiums to improve reading instruction in grades K-3, but little attention has been paid to efforts to improve student reading abilities in higher grades. The Florida school accountability legislation requires that all students show reading progress for each year they spend in school, with penalties for the schools where students do not perform well, and denial of a high school diploma for students who do not achieve the reading standard by the end of the twelfth grade. Since the implementation of school grading in 1998 in Florida, statewide reading achievement levels have been lower for middle and high school students than elementary students (Florida Department of Education, n.d.), indicating that many elementary schools are providing adequate reading instruction as measured by the Reading Florida Comprehensive Assessment Test (FCAT) for their students.

As students progress through school, the focus of reading instruction shifts from word recognition and decoding skills to reading comprehension and applying critical thinking skills. Studies of adolescents with reading difficulties show that their word attack skills and word recognition ability are at the third to fifth grade reading level (Curtis, 2002). In Florida, the Reading FCAT is a criterion-referenced test used to assess reading progress. The questions include multiple choice, short response, and extended response tasks, with the short and extended response tasks requiring the student to write his answer in a box with lines. The reading level of the passages chosen for inclusion on the FCAT is at the grade level being tested, based on the professional judgment of Florida educators. The FCAT reading cognitive task levels gradually change as students mature, with the third grade test having 70% knowledge and comprehension questions (Level I) and 30% analysis application questions (Level II), and the tenth grade test having 30% knowledge and comprehension questions (Level I), and 70% application and analysis questions (Level II). In addition, the type of text the student must analyze on the test changes. In the third grade, the FCAT has 60% literary text and 40% informational text, while in the tenth grade; the test has 30% literary text and 70% informational text (*FCAT Reading*, 2000).

On the both the Reading FCAT and Science FCAT, students must answer multiple choice, short response, and extended response questions. When answering the Reading FCAT extended response questions, students must analyze and apply the information in the passages they read. They are instructed that their answers must be inferred from the information given in the reading passage, and they must not add new content information even if they know it to be true. The rubric used for the reading extended-response questions states “the information is clearly text-based” (*FCAT 2004 Sample Test Materials*, 2003). However, on the extended-response questions on the Science FCAT (first given in 2003), the rubric states that students are expected to provide content information to explain or interpret the passages they read on the test (*FCAT 2004 Sample Test Materials*, 2003). This difference in the objectives of the extended-response questions on the two tests creates confusion among teachers, students, and others who want children to be successful on these high-stakes tests. Therefore, students must be taught how to answer the extended-response questions differently on each test, even though they appear to be very similar. Both science and language arts teachers must address the difference in seemingly similar FCAT questions, even though the objectives of reading comprehension and student inquiry are similar. This creates tension among teachers who must make decisions regarding how to spend their limited class time: Do they teaching reading, or inquiry? I believe they can do both.

After attending a week-long Project CRISS (Creating Independence through Student-owned Strategies) workshop in the late 1990s, I first began to think about teaching my science students to understand what they were reading and to apply metacognitive strategies when they read. I incorporated several of the reading strategies into my science instruction at all levels, teaching my students how to create their own vocabulary maps, KWL (Know, Want to learn, Learned) charts, and content frames using information from their textbooks. These particular strategies provide visual cues that help students understand content knowledge (see Appendix A). In April 2002, I attended a two-day MCREL (Mid-Continent Regional Educational Laboratory) Reading in the Content Area workshop for mathematics and science teachers. During that workshop, Deborah L. Jordan, co-author with Mary L. Barton of *Teaching Reading in Science: A Supplement to Teaching Reading in the Content Areas Teacher's Manual* (2001), claimed that reading science texts can be taught using the "5E" science instructional model. The phases of the "5E" model are engage, explore, explain, elaborate, and evaluate. This claim piqued my interest in learning how secondary science teachers have combined inquiry science instruction and reading instruction in the classroom. After the MCREL workshop, I contracted with the American Chemical Society to write content reading strategies for *ChemMatters*, their award-winning publication for high school science students. I realized the need for understanding the problems of integrating content reading strategies with science instruction that emphasizes student inquiry and scientific literacy when I learned of the positive reaction of teachers to the inclusion of content reading strategies in *ChemMatters* (H. Herlocker, personal communication, May 3, 2003). Further, I was involved in planning our school-wide reading initiatives for the 2002-2003 and 2003-2004 school years.

Statement of the Purpose

The purpose of this study was to determine how secondary science teachers report addressing scientific literacy acquisition of their students through teaching content area reading strategies and providing student inquiry opportunities in their classrooms. Since secondary science teachers in Florida have had eight years to integrate reading strategies into their science curricula, I expected to find evidence of successful implementation of teaching strategies that would benefit other science teachers who are attempting to include more student reading in their content-focused classrooms. I also expected that teachers who encourage student inquiry would report finding innovative ways to incorporate reading strategies into their curricula since often students read to facilitate inquiry.

Research Questions

1. How have more experienced secondary science teachers successfully addressed the scientific literacy of their students through integration of content reading strategies and student inquiry activities?

This study interpreted the experiences of secondary science teachers as they have attempted to solve the current dilemma of providing content area reading instruction while concurrently promoting the goal of scientific literacy for all described in the

National Science Education Standards (NRC, 1996) and *Science for All Americans* (Rutherford & Ahlgren, 1990). In this study, I hoped to find evidence for how scientific literacy has been addressed in Florida's secondary science classrooms by teaching both content reading strategies as well as processes of scientific inquiry.

2. How do teachers use reading in science?

Even though most secondary science students have already acquired basic reading skills such as decoding and word recognition, teachers must address the need for students to develop reading strategies that are content specific. I wanted to learn how secondary science teachers use textbooks and other reading materials to provide science content for students and facilitate student achievement of national and state science standards

3. How can secondary science content reading strategies be improved to promote scientific thinking?

With the national and statewide emphasis on the importance of reading for all students, along with the implementation of national and state science standards, I expected to find experienced science teachers actively searching for and experimenting with methods that incorporate reading and inquiry strategies into their instruction. Determining which reading strategies they found most useful and applicable to science inquiry instruction would help less experienced teachers and professional development educators plan meaningful science instruction. I intended to describe the successful integration of content reading and inquiry skills in science classrooms, along with the materials and instructional strategies teachers have implemented to balance these instructional goals.

Methodology

There are few examples in the literature of successful integration of science reading strategies into inquiry-based classrooms, or the integration of student inquiry into text-based classrooms. Therefore, a qualitative grounded theory design methodology was chosen to determine how teachers incorporate reading in their secondary science classrooms. Grounded theory, a systematic qualitative research methodology first described by Glaser and Strauss (1967), is an inductive naturalistic inquiry method that allows flexibility which is important when working with people who have tacit knowledge of their subject (Lancy, 1993). The method of data collection was focus group sessions and individual interviews of actual secondary science teachers in Florida. The focus group participants were invited because of their interest in secondary science instruction as shown by their attendance at the meetings where the focus groups were held. The individuals interviewed were a convenience sample from the rural district where I teach. Before any questioning began, I gained informed consent by giving prospective participants letters to sign (Appendix B). All participants received copies of the informed consent letter.

A semi-structured focus group was held at the Florida Association of Science Teachers (FAST) annual conference in Jacksonville on October 18, 2003. Both teachers who use reading strategies to teach science and those who want to include reading strategies in their science instruction were asked to attend the focus group. The second focus group was held during a meeting of the FCAT Science Item Review Committee on October 28, 2003. The third focus group was held during the Junior Science, Engineering, and Humanities Symposium at the University of Florida on February 3,

2004. Individual interviews using similar questions were also conducted with six secondary science teachers and one reading specialist from Hendry County, Florida, a small rural south Florida school district. All of the focus groups and interviews were audiotaped for accuracy in transcription. The individual interviews, focus group sessions, and discussion generated provided an overview of how those secondary science teachers from Florida have addressed teaching content reading skills and processes of scientific inquiry in the context of scientific literacy.

The data were analyzed using the constant comparative method described by Glaser and Strauss (1967). This involved using an open coding process (Creswell, 2002) to reduce the textual data to a few salient categories related to teaching content area reading strategies and inquiry skills in the context of scientific literacy. The categories were determined by dividing the text into segments, coding these segments, searching for and reducing redundancy in the codes, and finally collapsing the codes into conceptual themes that describe how teachers address content area reading and inquiry skills. I looked for patterns and processes teachers applied when choosing instructional reading strategies and reading materials as well as examples of successful integration of content area reading and inquiry skills that the teachers reported implementing in their classrooms.

Interview questions

1. Do you ever combine student inquiry with reading activities? Please give examples.
2. What reading problems do your students have?

3. What reading strategies do you teach your students to use in science?
4. How do you address scientific literacy in your classroom?

Definitions

Content area literacy – language skills including reading, writing, speaking, listening, and media literacy (Thier, 2002).

Student inquiry - "activities . . . to develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (NRC, 1996, p. 23). "It is a process of investigation, observation, and interpreting results." (Enger & Yager, 2001, p. 4)

Scientific literacy - "knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (NRC, 1996, p. 22).

Limitations

A limitation of all grounded theory studies is that the research findings apply only to the situations under investigation, so if conditions change, the generated theory would not hold. The limitations of focus groups include the verbal self-reported behavior of the participants, the interaction of the participants during discussions, and how the focus groups are managed by the moderator. Another limitation of the proposed study was the self-selection of teachers for the focus groups. In general, science teachers who are involved in curricular decision making and those who have a desire to improve their practice attended the meetings where the focus groups were held. Also, the location of the focus group sessions in northern Florida meant that more teachers from that region of the state were represented. Some of the regional bias was eliminated by interviewing teachers in south central Florida. Finally, as a teacher researcher, my preferences for teaching student inquiry, process skills, and critical thinking must be recognized, as well as my openness to changing my practice.

Assumptions

One assumption of this study was that Florida science teachers' concerns regarding teaching content reading strategies and student inquiry skills in the context of scientific literacy mirror the concerns of teachers nationwide. While Florida's Sunshine State Standards for science share similarities with both the *National Science Education Standards* (NRC, 1996) and the call for scientific literacy expressed in *Science for All Americans* (Rutherford & Ahlgren, 1990), there are some differences. The major difference is the emphasis on specific science content of Florida's standards compared to the national standards. In addition, Florida's rewards and sanctions related to school performance on the Florida Comprehensive Assessment Tests in reading and math may have caused Florida's science teachers to change their instruction in a manner different from science teachers in states without such measures.

CHAPTER TWO: REVIEW OF THE LITERATURE

Introduction

The goal of this study was to interpret the experiences of secondary science teachers as they work to incorporate inquiry activities and content reading strategies into their curricula. As they teach, secondary science teachers address not only science content and concepts, but also inquiry skills, scientific thinking, and scientific literacy of their students. Yager (2004) asserts that the abilities of scientific inquiry support scientific literacy. Consciously and unconsciously, teachers decide what is the most efficient way to help their students understand both the concepts and processes of science, and they construct learning environments that support student learning. Kamil and Bernhardt (2004) state, “Although researchers have many suggestive findings about the connections between science learning and reading, educators need a far more detailed description of the connections” (p. 127). There is no doubt that students must be able to read to learn science at the secondary level, and I believe that science teachers can help students establish this connection. This literature review will begin by describing professional practices of secondary science teachers and teacher beliefs that may provide insight into how science teachers have successfully addressed the scientific literacy of their students through integration of content reading strategies and student inquiry activities. Next, I will elucidate the context for reading in secondary science classrooms through an overview of science content and concepts included in national and state standards as well as science textbooks. Finally, I will investigate the relationship of student inquiry and scientific thinking to reading practices and student metacognition.

Professional Practice of Science Teachers

In the United States, the science curriculum reform programs of the 1960s were designed for only the best students in order to close what was perceived as a technological gap between the United States and the Soviet Union after the launch of Sputnik in 1957. That is in marked contrast to today's science reforms such as Project 2061, begun by the American Association for the Advancement of Science in 1985, that call for educating all students to become scientifically literate citizens, able to make informed decisions regarding personal and community health, regardless of their aspirations after high school (Rutherford & Ahlgren, 1990). As long ago as 1960, Schwab (1960/2000) recognized that simply lecturing, reading the textbook, and testing would be inadequate for science teaching in the future. The curricular changes of the 1950s, 1960s, and 1970s encouraged inquiry skills development and understanding of science as inquiry. However, these curricular reforms were usually written by scientists without regard for curriculum and instruction principles. The result was a failure to motivate those students who found the abstract nature of the reforms difficult, and a failure to address scientific literacy for all students (DeBoer, 1991). The idea of scientific literacy for all was foreshadowed in 1960, when Schwab (1960/2000) called for "enquiry into enquiry," declaring that we need scientists as well as nonscientists who understand the work of scientists. Bybee and DeBoer (1994) claim that there are three goals for teaching science: personal development and improvement of society; knowledge of scientific facts and principles; and understanding and application of scientific methods. They add that "Society needs scientific literacy" (p. 376). Today, scientific knowledge is viewed as a temporary explanation that best fits the existing evidence and current thinking (Yore, 2004). As a veteran science teacher, I believe that students must understand how we know, what evidence there is for our scientific knowledge, both in order to develop deep understanding and to make informed decisions as citizens in our society.

Since 1995, Florida's Sunshine State Standards for Science have described what all students in Florida should know, but many educators are unsure of how to proceed as we move from science for the intellectually elite to "science for all" because this represents a shift from how most science teachers themselves learned science. Now that many science teachers believe they must modify their teaching practices so that their students can meet the science standards, there is tension between how successful science teaching used to look and how successful science teaching should look. "It is difficult to teach in ways in which one has not learned" (Loucks-Horsley, Hewson, Love, & Stiles, 1998, p. 1). An inquiry-based classroom demands a teacher with a high level of expertise who is willing to embrace inquiry as both content and pedagogy while being actively involved with her students (Crawford, 2000). In a study investigating barriers to teaching reform, Wasley et al. (1995) found that exceptional teachers who were committed to reform wanted approaches and strategies, or heuristics, but not recipes, to guide their practice. National and state standards state outcomes describe what students should know and be able to do, but they do not give specific procedures for teachers to follow, nor should they, because we must allow for a diversity of teaching and learning styles.

However, secondary science teachers need support as they strive to modify their practice so that their students can achieve the standards (Valencia & Wixson, 2000).

The teacher's role in teaching explicit reading and writing skills to students who are actively engaged in studying natural phenomena is critical (Alvermann & Moore, 1996; Century et al., 2002; Loring, 1997). Many secondary science teachers do not want to be reading teachers because they believe reading to be boring and far less interesting than doing science. Some teachers who majored in science chose science because of the lack of reading and writing requirements compared to other majors (Donahue, 2000). Until high-stakes reading tests were adopted by states, secondary teachers had little or no training in how to teach reading skills, despite more than a half century of calls for reading reform at the secondary level (Bintz, 1997). At best, only one methods course in content area reading was required for secondary science certification, so science teachers who entered the field more than a few years ago often feel unprepared to teach reading. Many of those who majored in science want to share their love of the subject with their students through exciting demonstrations, lectures, and labs, and the necessity of teaching content reading may be disregarded by those teachers.

Teacher Beliefs

Teacher beliefs and knowledge are the most important factors determining instructional choices and curriculum implementation, and they are critical for goal setting and planning (Loucks-Horsley, et al., 1998). These beliefs are influenced by teachers' prior experience and attitudes (Tobin et al., 1994; Readence, Kile, & Mallette, 1998). In many teachers' eyes, the standards movement has strengthened the idea that they must "cover the content." Furthermore, most teacher education courses have reinforced the notion of *science as a noun*, emphasizing voluminous science content, rather than *science as a verb* [italics in original], emphasizing the human aspect of science as inquiry (Yore, 2004). Yore found this especially troubling in view of a recent survey about scientists' views of science that demonstrated their beliefs about science are evaluativist rather than absolutist or relativist. Many people think of science as a collection of facts in a book, but "facts in themselves do not provide an understanding of the world" (Duschl, 1990, p. 50). Gardner (1991) cautions that in the push to "cover" the content we may be undermining more important educational goals such as understanding how to use skills and concepts once our students leave school. I believe this understanding comes from active student engagement in both inquiry and reading.

As secondary science teachers plan implementation of standards-based instruction, the admonitions from the *National Science Education Standards* (NRC, 1996) and *Science for All Americans* (Rutherford & Ahlgren, 1990) include "less is more" and "depth over breadth." Fundamental changes that would facilitate in-depth learning are replacing large amounts of information with major conceptual themes, and implementing an interdisciplinary approach among the sciences, emphasizing connections to other disciplines (Bybee & DeBoer, 1994). Although the science curriculum efforts of the 1960s emphasized student inquiry, many teachers continue to teach the way they learned, focusing on textbook learning of content and "cookbook" labs, believing this approach to be more efficient as they try to ensure their students achieve at a high level. Most teachers use the transmission approach to teaching, which is content centered, teacher controlled, and uses the textbook authoritatively as a curriculum guide. However, this approach may fail to engage students, it does not lead to deep understanding, and textbooks could have organizational or factual problems. According to Alvermann and Moore (1996), the reasons for observed secondary reading regularities include maintaining classroom order, covering course content for accountability, socializing student behavior by conveying approved knowledge, and making efficient use of resources such as time and materials. They conclude that "traditional teaching practices might prevail because they are what teachers know best" (p. 973). Indeed, the practice of "covering the content" may be reinforced by the standards movement, hindering student growth in learning how to learn on their own. However, helping our students become independent learners should be the goal of all teachers.

Science Standards

After the publication of *A Nation at Risk* in 1983 (National Commission on Excellence in Education), policy makers began examining what American students should know and be able to do. In the 1980s, more than 300 reports called for a reform of science education, with fairly consistent recommendations (Bybee & DeBoer, 1994). This dissatisfaction eventually led to an emphasis on accountability in schools nationwide, and in 1998, Florida began administering the FCAT annually to students in writing, language arts, and mathematics. During the past 20 years, standards and high-stakes tests have emphasized acquisition of literacy skills, but not necessarily scientific literacy. At workshops and conferences I have attended during the past six years, I heard science teachers searching for effective ways to integrate reading into their instruction without sacrificing the thrill of discovery through inquiry activities. It is interesting to note that two standards (1 and 7) in the *Standards for the English Language Arts* particularly apply to scientific literacy:

> 1. Students read a wide range of print and nonprint texts to build an understanding of texts, of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classic and contemporary works.
>
> 7. Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience. (from Wilkinson, 1999, p. 157-158)

Since these commonalities among language arts and science standards exist, it would seem that creative teachers may already be integrating student inquiry with reading in the science classroom because neither reading nor inquiry alone is sufficient to learn science (Donahue, 2000).

Benchmarks for Scientific Literacy (Project 2061), published in 1993, and the *National Science Education Standards* (NRC), published in 1996, have similar content goals (Bybee, 1997). The emphasis of Project 2061 publications is that all scientific disciplines rely on evidence, development of hypotheses and theories, observation, and logic (Rutherford & Ahlgren, 1990). The *National Science Education Standards* (NRC, 1996) emphasize scientific processes, inquiry, and skills development. Bybee (1997) foresaw the push for the goal of scientific literacy for all in the national standards, which are after all, policy guides, not curriculum materials. Many states, including Florida, already have mandated science assessments based on state frameworks that guide curriculum orientation and include specific topics in physical science, earth science, and life science, as well as the nature of science. In 2003, the first statewide Science Florida Comprehensive Assessment test (FCAT) was administered to students in grades 5, 8, and 10. Currently, plans are for FCAT science results to be included in Florida's school grade calculations beginning in the 2006-2007 school year. The No Child Left Behind (NCLB) Act of 2001 demands science testing in all states by the 2007-2008 school year, using standards developed by the states, most of which relied on the *NSES*. However, there are no guidelines at present for incorporating science into the Adequate Yearly Progress requirements of the NCLB. Even so, most science teachers feel pressure to help their students achieve at high levels on both science and reading tests.

Textbooks

Bybee (1997) claimed "we already have a national science curriculum. It is comprised of extant textbooks." Textbooks determine 75-90 per cent of the instructional content in schools nationwide, according to some estimates (Chambliss & Calfee, 1998). The conclusion of Yore, Bisanz, and Hand (2003), examining studies of science reading from 1978-1993, was that textbook choices determine curricular themes such as science content, concepts, and processes, and how instruction was delivered, but laboratory workbooks were used to support inquiry learning. By far, textbooks are the most widely used reading materials in science classrooms (Alvermann & Moore, 1996; Strong, Perini, Silver, & Tuculescu, 2002; Yore et al., 2003). The comprehensive content of most textbooks make them popular with teachers who depend on them to provide factual information (Alvermann & Moore, 1996). However, textbook understanding is mostly superficial and does not help students develop deep conceptual understanding of important science concepts, and they may be sources of student misconceptions (Thier, 2002; Wandersee, Mintzes, & Novak, 1994;). Furthermore, science textbook readability is often above grade level, although it can vary within textbooks and across disciplines, and attempts to improve reading comprehension by using four colors and visual aids has not helped all students (Yore et al., 2003). Middle school science books often contain four to five thousand specialized or technical words that are seldom linked to students' prior knowledge, and this encyclopedic coverage causes the big ideas in science to be obscured from students trying to make sense of the text (Chambliss & Calfee, 1998).

Even though teachers feel that they must cover state-mandated content using state-adopted textbooks, little textbook reading is assigned (Bean, 2000; Tobin et al., 1994; Wade & Moje, 2000). Allington (2002) claims that most students find textbook reading too difficult, with too many unfamiliar words, so they cannot read them fluently and with understanding. Consequently, students frequently depend on teachers' presentations including lectures, discussions, and films, and use the textbook only for verification (Alvermann & Moore, 1996). Newer science textbooks are visually captivating, with dramatic photographs and satellite images to capture student attention. In addition, they come with many desirable supplemental features and ancillary materials to guide teachers in presenting science lessons (Chambliss & Calfee, 1998). These textbooks are very popular with teachers who are looking for a "quick fix" as they plan lessons, giving further support to Bybee's claim (1997).

Student Inquiry

The national standards call for active student engagement in using inquiry methods as they learn the processes of science. The *National Science Education Standards* (NRC) state:

> Inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills. (p. 15)

Inquiry combines process skills with scientific knowledge to deepen understanding by engaging the learner, searching for evidence, explaining, evaluating, and communicating information (NRC, 2000). The *NSES* (NRC, 1996) state that inquiry is both a learning goal and a method of teaching that must be learned with the subject matter, not in isolation. In my study, the teachers were asked to report on acquisition of student inquiry skills to achieve understanding of the nature of science, not inquiry as a teaching method. The inquiry standards can be met only when students engage in active inquiry. By exploring the nature of science and scientific inquiry, science educators can help students acquire scientific knowledge in a process similar to the process of learning (Duschl, 1990).

In the guide to the “Science as Inquiry” standard of the *NSES* (NRC, 1996) there are seven abilities of scientific inquiry that students need to develop:

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Communicate and defend a scientific argument.
- Develop understandings about scientific inquiry. (pp. 175-176)

Certainly, students must be able to read to meet this standard. Holliday et al. (1994) claim that an effective learning community consists of student-designed inquiry based on student-selected problems combined with supportive teachers who provide "multiple information sources and explicit strategy instruction" (p. 888).

"The goal of scientific inquiry is the development of scientific understanding" (Duschl, 1990, p. 49). Numerous studies have shown that student misconceptions in science are deep-seated and difficult to change (Guzzetti, 2000; Herron & Nurrenbern, 1999; Hewson, 1992; Phillips & Norris, 1999). Allowing students to construct their own knowledge through laboratory inquiry as well as reading and writing about science may help alleviate this problem (Glynn & Muth, 1994). Reading alone is insufficient for conceptual change to occur, allowing students to replace their alternative conceptions with scientific ones; however, studying the history of science may help students discover their conceptual weaknesses (Wandersee et al., 1994). Yager (2004) claims that there must be a context for science learning to make it personally useful to students so that they will choose to learn. Furthermore, by teaching science in context, and acknowledging students' prior knowledge, we can demonstrate how scientists reason. This may be accomplished by addressing students' naïve conceptions and teaching procedural knowledge (Duschl, 1990). Additionally, processes must be learned in real-life contexts, not as individual skills (Yager, 2000).

Many educators from all content areas have championed the concept of constructivist learning to help students learn in context through concrete experiences as they develop critical thinking skills (DeBoer, 1991). The goal of constructivist learning is deep understanding, not mimetic behavior that will be forgotten in a few days or weeks (Brooks & Brooks, 1993). Constructivism has roots in John Dewey's philosophy of education because he believed that children are naturally curious (1902/1990). Psychologist Jean Piaget's work led him to conclude that a learner constructs knowledge in developmental steps based on his experiences (Brooks & Brooks, 1993). According to Vygotsky (1987), successful instruction and the resulting intellectual development of the learner depends on introducing him to that which lies within the *zone of proximal development*, or the intellectual potential of the learner at that point in time. This is achieved in collaboration with the learner as she progresses from the concrete to the abstract, but the learner advances only to a certain limit. It is unreasonable to expect learners to apply a reading strategies that they have not used previously, therefore teachers must provide scaffolding, so that with practice the learner can apply the reading strategies without help (Alvermann & Moore, 1996). Many science educators have turned to constructivism for solutions to the problem of educating a scientifically literate populace (Brown, Collins, & Duguid,1989; Doran, Chan, & Tamir,1998). However, students who have been successful in science by memorizing facts and algorithms are resistant to a change in instruction. Bereiter (1990) argues that many children develop a stable "schoolwork module" as they adapt to school, and when the child is asked to learn in a different way, there may be resistance because the child may consider the work too difficult. Parents may also question an instructional strategy that is unfamiliar to them.

Kamil and Bernhardt (2004) found it "bitterly ironic" that most science education literature has ignored previous written data regarding how to teach knowledge construction and verification of data, because that is what scientists must do to pursue their professional goals. Students should form questions and problems with direction from the teacher, then become actively involved in the process of inquiry and problem solving (Bybee & DeBoer, 1994). Constructivism involves active generation and testing of alternative possibilities, a process that is analogous to a scientist generating and testing hypotheses (Lawson, 1994). However, Pratt and Pratt (2004) caution that while the object of learning in science is understanding physical phenomena in the natural world, the object of reading comprehension is understanding content described in the text. They state, "The challenge of classrooms today is to bring the supportive skills from literacy and inquiry science together in a truly integrated way to support the goal of learning science content" (p. 397).

Yore (2004) emphasizes that scientists construct meaning as they read to inform their actions as they perform research and write reports. "As long as text remains a critical mediating factor in the storage, transmission, and retrieval of scientific information, reading will remain a critical science skill" (Kamil & Bernhardt, 2004, p. 138). Baker (2004) found the following passage from the *NSES* (NRC, 1996, p. 33) in which the word “reading” could easily be substituted for “science,” emphasizing the commonalities in reading comprehension and scientific inquiry:

> In successful science classrooms, teachers and students collaborate in the pursuit of ideas, and students quite often initiate new activities related to an inquiry. Students formulate questions and devise ways to answer them, they collect data and decide how to represent it, they organize data to generate knowledge, and they test the reliability of the knowledge they have generated. As they proceed, students explain and justify their work to themselves and to one another, learn to cope with problems such as the limitations of equipment, and react to challenges posed by the teacher and classmates. Students assess the efficacy of their efforts—they evaluate the data they have collected, re-examining or collecting more if necessary, and making statements about the generalizability of their findings. They plan and make presentations to the rest of the class about their work and accept and react to the constructive criticism of others. (p. 243)

“Succinctly stated, decent science interaction must embrace inquiry; without inquiry, the activity called science is not really science at all.” (Saul, 2004, p. 448). Children’s ability to do science does not relate to their ability to verify knowledge from text (Kamil & Bernhardt, 2004). Barton & Jordan (2001) claim that instruction in reading strategies can help students become scientifically literate when science teachers use the “5E” instructional model to engage, explore, explain, elaborate, and evaluate when learning new science concepts. Since science is more than laboratory work, students should be encouraged to communicate and explore using scientific language in a context of inquiry if they are to understand scientific reasoning and become scientifically literate. Integrated reading and writing activities support active inquiry in real-world contexts (Glynn & Muth, 1994).

Students become scientifically literate through both reading scientific information and inquiring to understand how scientific information is validated. Armbruster (1992/1993) argues that since reading and doing science have the same cognitive base, they have a synergistic relationship that helps students interact while they construct new knowledge and engage in critical thinking. Other researchers agree that reading and inquiry are active processes that are necessary for learning science, so science content reading and processes of inquiry can be effectively integrated in science classrooms in order to reach the goal of scientific literacy for all (Donahue, 2000; Osborne, 2002). "Hands-on" science may be insufficient for students to develop deep understanding, so teaching science and reading together would tend to reinforce both concepts as constructive processes that require critical thinking. The *National Science Education Standards* (NRC, 1996) caution teachers that "Conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry" (p. 23).

Alvermann (2004) posits that the tensions between doing science (inquiry) and reading and writing science have eased, and good teachers use many forms of literacy to engage students in inquiry. In order to accomplish this, teachers provide explicit instruction using a range of reading tasks intended to integrate reading instruction into the science curriculum (Yore, 2004). Saul (2004) cautions that although linking literacy and science is needed, it doesn't save time because we can't substitute reading for inquiry.

Reading Strategies

Alvermann and Moore (1996) found that although reading is closely connected to other forms of classroom communication in secondary classrooms, there were few examples of continuous reading (more than 15 seconds), students often spent reading time searching for bits of information, very little oral reading was observed, and reading most often played only a supportive role. Most textbook assignments involve only lower level thinking skills, such as recall and recognition, or application of an algorithm to problem solving. Consequently, even successful students often find school reading unpleasant, not useful, disjointed, and unconnected to their personal interests (Moore, Bean, Birdyshaw, & Rycik, 1999). Perhaps even more problematic is the desire of many high achieving students to simply memorize facts and avoid making connections or applying knowledge to new situations. These students make teaching science through inquiry and application of science knowledge even more challenging for their teachers (Gallagher, 2000).

The reality is that although most secondary students can decode or recite the words, many cannot comprehend and apply critical thinking skills to informational text. Furthermore, in the lower grades narrative text is read more than informational text, but skills specific to informational text need to be taught. Some text differences that Kamil and Bernhardt (2004) identify are that informational text can often stand alone in “self-sustaining chunks,” it has cues that aid the reader, and the reader must assume the informational text is true. In science, students read text uncritically, readily accepting claims made by the author even when they disagree with the author (Phillips & Norris, 1999). This acceptance that whatever they read is true does not lead to student learning, so the research suggests that teachers must know how to address reading comprehension and naïve conceptions in science. For enduring knowledge and understanding, the teacher must facilitate and direct learning through questioning and posing problems, enabling students to reorganize their mental structures, recognize and give up their incorrect strategies, and find new ones (Lawson, 1994).

Gardner (1991) claims that in order to read for understanding and have a desire to read, students must have a familiar context for reading, so teachers must activate students' prior knowledge and giving them a purpose and strategy for reading. As students progress through school, the thrust of reading comprehension shifts from student reproduction of information in a text to the active construction of meaning from the text (Beers, 2003; Buehl, 1995). Thier (2002) advocates that teachers in both inquiry-based and textbook-based classrooms should model reciprocal teaching strategies for students including pre-reading, active reading, and post-reading activities. Through reading "real" books and articles, not just the textbook, students can learn thinking skills that effective readers use (Wilhelm et al., 2001; Daniels & Zemelman, 2004).

Many secondary science teachers have learned how to use content reading strategies such as those described in *Project CRISS: Creating Independence through Student-owned Strategies* (Santa, Havens, & Maycumber, 1996) because of the influence of language arts standards and high-stakes testing of reading comprehension using informational text. This training encourages teachers to activate students' prior knowledge, establish a purpose for reading, and encourage student reflection on how their understanding changes as they synthesize new information from reading (Strong et al., 2002). Reading strategies help students' attitudes toward reading improve as they achieve greater literacy skills, but teachers should stress that there is no one “right” strategy for reading a particular text. Explicit instruction, modeling, explaining, demonstrating, and even reading aloud while describing thinking processes will support students as they acquire complex literacy strategies (Allington, 1994; Loring, 1997). Content reading strategies purport to increase student independence and facilitate understanding, claims that are also made for inquiry methods (Tobin et al., 1994). However, teachers must spend time to incorporate reading strategies sequentially and repeatedly in a developmentally appropriate manner for students to learn how to use them (Yore, 2004). This would be easier for classroom teachers if they collaborated with literacy experts to develop strategies for vocabulary, comprehension, and fluency that are discipline-specific, then published these strategies in teacher’s guides provided by textbook publishers (Shanahan, 2004). Strong et al. (2002) suggest some specific strategies to help engage students in active reading of their textbooks, including organizers to recognize text structure, peer reading and summarizing, and questioning the author because textbooks are not infallible.

Most teachers believe that the content of science courses is relevant to students’ lives (DeBoer, 1991), yet many students find literacy activities at school uninteresting and irrelevant to their lives (O’Brien, 1998). This disconnect may be due to the fact that not much research has been done on secondary teachers’ beliefs regarding literacy in content areas (Readence et al., 1998). Reading is be active, and engaged readers are far from bored. Reading science requires knowledge of some unique text features and strategies, such as how to interpret tables and graphs, that are different from other subjects (Roth & McGinn, 1998). Glynn and Muth (1994) suggest that science students read a variety of text to gain reading fluency, including:

1. Newspaper stories about new developments in science and technology. Excellent stories can also be found in magazines, such as *Science News*, *National Geographic*, *Natural History*, *Discover*, and *Smithsonian*.
2. Trade books on a variety of science topics.
3. Different textbooks as references, comparing their explanations of topics.
4. Biographies of scientists, particularly of those from groups that have been traditionally underrepresented in science.
5. The award-winning prose of scientists, such as Lewis Thomas (1974), author of *The Lives of A Cell.*
6. Highly acclaimed science fiction stories, such as those written by Isaac Asimov and Arthur C. Clarke. (p. 1062)

This diversity of text enables students to choose reading that is interesting to them while they improve their scientific literacy by learning important science concepts that address social and personal issues. The amount of reading correlates positively with higher reading achievement and knowledge levels, and fosters more active citizenship (Guthrie & Anderson, 1999), so discovering how to motivate students to read more would promote scientific literacy. Century et al. (2002) claim that teachers must help students develop facility with language by having a purpose for reading and writing, planning how to use the text, and deciding how reading and writing support inquiry learning. With the Internet being used more and more often by students for research projects, teachers face special challenges. Even with explicit instruction, Yore et al.

(2003) found that students had difficulty evaluating Internet web sites because they tended to simply match words, overemphasized the search process, and failed to try to substantiate information.

Yore (2004) summarized several strategies that can improve student understanding of science, if explicitly taught:

- Assessing the importance, validity, and certainty of textual claims
- Generating questions about the topic to set the purpose for reading
- Detecting main ideas and summarizing them
- Inferring meaning
- Skimming, elaborating, and sequencing
- Utilizing text structure to anticipate and comprehend ideas
- Improving conceptual networks (concept mapping) and memory
- Monitoring comprehension
- Self-regulating to address comprehension failures. (p. 88-89)

Loring (1997) advocates teaching reading as thinking by helping students learn reading process strategies with metacognitive awareness that helps students develop internal motivation. Many science educators (Baker, 2004; Bransford, Brown, & Cocking, 2000; Thier, 2002) believe that if students' metacognitive skills improve, their reading comprehension and science inquiry skills will improve. Baker (2004) claims that metacognition is necessary both for the "successful application of science process skills" and "the successful interpretation of science text" (p. 250). Readers of science must switch between informational text and compare the information to what they already know by using experience and environmental clues, requiring active involvement of the learner (Wandersee, et al., 1994; Yore, et al., 2003). Thier (2002) suggests that metacognitive strategies can be improved when students make reading personal by writing a list of questions they have after previewing a reading. Baker's (2004) recommendations are:

> (a) scaffolded instruction should focus on multiple strategies and skills in context/ (b) promoting metacognition should not be seen as an end in itself; (c) students need to develop and apply a critical stance toward the information they encounter; (d) teachers should recognize that it is hard work fostering metacognition and that peer support can be beneficial; (e) students need to learn to assess their own progress and understandings; and (f) students should be provided with frequent opportunities to share their ideas with their peers. (p. 254)

Wandersee et al. (1994) caution that, although metacognition promotes meaningful learning, it requires effort, so it should not be regarded as a "quick fix."

Summary

Since Florida's secondary science teachers have been required to include reading and science standards for the past eight years as they plan their daily instruction, I expected to find evidence of the successful integration of meaningful content reading strategies, engaging text, and student inquiry activities. Reporting on these successful connections of science and reading would help both new and experienced teachers make significant changes in their science teaching. With the emphasis on both reading and science standards in Florida, there is a necessity for secondary science teachers to integrate reading and science instruction in their classrooms and that can be done by using student inquiry and reading strategies that engage all students.

Reading comprehension is a prerequisite to learning new information, especially in science where new data obtained daily creates new knowledge and understanding. Textbooks should not be the only source of scientific information that students read because they are often superficial , lacking details that some students want to know about specific topics, and they are not the most current source of scientific information. Providing a meaningful context for learning would encourage students to read a variety of sources including magazines, books, and electronic sources as they research new information.

Reading strategies that support inquiry include activation of prior knowledge, establishing a purpose for reading, and encouraging metacognition. Teachers who are attempting to improve their students' reading comprehension and scientific literacy can do this effectively by incorporating some constructive reading strategies into their instruction. Many science and reading researchers believe that all students can become scientifically literate through learning to inquire and read using metacognitive strategies (Baker, 2004; Thier, 2002). As students learn to inquire by reading independently, they could be encouraged to search for evidence to support new scientific learning.

CHAPTER THREE: METHODOLOGY

Grounded Theory

Qualitative research seeks to interpret and understand the experiences of the participants through a variety of interconnected methods that expand rather than control the research variables (Denzin & Lincoln, 1998; Holliday, 2002). Grounded theory is a systematic qualitative research methodology first described in detail by Glaser and Strauss (1967). The main goal of grounded theory is to generate, not verify, a credible theory that explains or predicts the experience of the group being investigated. However, Glaser (1992) cautions against forcing the data into pre-conceived categories.

The purpose of this study was to describe how secondary science teachers report addressing scientific literacy acquisition of their students through a combination of teaching for knowledge of concepts using content area reading strategies, and teaching for understanding the processes of science using an inquiry approach. Since the study aimed to inquire about how teachers connect teaching reading and science effectively, I chose grounded theory methodology because of its ability to describe and generate a theory about the phenomenon under investigation. Although much research has been done on the effectiveness of different reading strategies and the relationship to student inquiry (Baker, 2004; Holliday et al., 1994), actual teacher use and integration into regular science classroom instruction has not been documented. Grounded theory allowed me the flexibility to explore teachers' tacit knowledge about the integration of reading and science instruction. Grounded theory is useful in contributing to knowledge of the discipline, it gives participants a voice, and it can be relevant to policy making (Strauss & Corbin, 1998).

Unstructured, open-ended interviews were used to collect data for grounded theory development with the purpose of finding multiple perspectives. Although less structure is better for exploratory research such as grounded theory, the lack of structure makes data analysis difficult (Morgan, 1997). The questions used in this study were broad and nondirective in order to allow for a wide range of interpretation and meaning from the teachers (Fontana & Frey, 2000). However, we must move beyond simply telling about classroom experiences as we attempt to make teachers' tacit knowledge explicit (Loughran, Mitchell, & Mitchell, 2003). Perspectives gained from being interviewed may change practitioners' actions or attitudes when interviews are used to collect data (Charmaz, 2003). Morgan (1997) stressed that focus group participants must be highly involved with the topic under discussion so that their points of view can be emphasized, with a low level of moderator involvement. Two 8-person focus groups provide as many ideas as 10 individual interviews, according to Fern (1982, quoted in Morgan, 1997). Small groups provide more information and more accurate information because there is no need to respond to a given question, if the moderator can handle disruption by uncooperative participants or those who consider themselves "experts" (Morgan, 1997; Osborne & Collins, 2001).

After data collection, the researcher engages in the coding process using the constant comparative method, a systematic inductive approach using joint coding and analysis (Glaser & Strauss, 1967). The coding process may begin when the first aliquot of data is collected, so that information gained may guide further data collection. Open coding is used to describe initial categories, followed by axial coding wherein the data are reassembled through comparison and integration to identify a central phenomenon (Creswell, 1998). During open coding, the researcher should have no preconceived ideas for coding the data (Glaser, 1992). When engaged in the constant comparative process, memo writing helps the researcher remain reflexive so that fresh ideas and new relationships can be discovered (Charmaz, 2003). Theoretical coding with constant comparison produces conceptually rich theory, if the research has theoretical sensitivity, ". . . the disciplinary or professional knowledge, as well as both research and personal experiences, that the researcher brings to his or her inquiry" (Strauss & Corbin, 1998, p. 173). The researcher must continually make comparisons with the goal of producing "conceptually dense" theory with many conceptual relationships describing patterns and processes. The research is brought to a close when the categories are saturated, meaning that no more new information can be found that relates to the topic under investigation.

Theoretical Framework

This research was guided by a constructivist paradigm with the assumption that teachers chose which teaching methods to implement according to the meanings they have constructed to explain their teaching situation (Moore & Readence, 2001). In particular, I wanted to learn how teachers have addressed teaching content area reading skills in their contemporary science classrooms where inquiry and scientific literacy must be addressed in order to meet national and state science standards. In this grounded theory study, I searched for insights into the informants' descriptions of their situations as I attempted to capture their perceived realities from an emic perspective. The pedagogical content knowledge of the teachers interviewed was examined in a holistic search to find meaning in how those teachers reported incorporating reading into their secondary science curricula. Pedagogical content knowledge recognizes that effective science teachers "integrate science content knowledge, science education research, science teaching experience, and principles of pedagogy" (Wandersee et al.,1994, p. 199). The culture of the teacher informants was dynamic, influenced by external factors such as national and state standards, adopted textbooks, and local school administrators.

Although qualitative research is interpretive, the balance between creative exploration and maintenance of principles can be struck by explicitly showing the steps and methods used (Holliday, 2002). In order to triangulate the data, I continually made comparisons among what teachers reported, including their classroom practices and perceptions of good science teaching, and how they connected their beliefs and practices with student learning through reading and inquiry. It is important to note that the interpretations provided by grounded theory are provisional, and limited to the conditions existing at the time the theory was developed. Therefore, grounded theory is open to further theory development with the goal of producing, rather than testing, theory (Strauss & Corbin, 1998).

Grounded theory may be constructivist or objectivist (Charmaz, 2003). In the constructivist approach, the researcher relies on the data as well as the analysis created by the researcher based on the "shared experiences" of the researcher and participants to generate theory. Objectivist grounded theory has a more positivist approach to generating theory, with the researcher assuming an unbiased, separate approach to the data (Charmaz, 2003). Denzin and Lincoln (1998) claim that all observations are subjective because they are socially situated in the interactions of the participants and the researcher. Due to my insider status as a fellow teacher, I employed a constructivist approach to analyze the problem through gathering data and searching for explicit themes in what teachers reported. Through thick description, showing the interconnectedness of the data, I expected to work up from the data to construct theory that may be informative in curriculum planning (Holliday, 2002). Throughout, I was attentive to connections teachers made among teaching reading strategies, scientific literacy, and student inquiry. Finally, I chose two of the focus group participants to compare how the theoretical model that I developed could be applied to actual classroom teachers.

Selection of Participants

Since many Florida science teachers have been required by their administrators to incorporate FCAT reading strategies into their secondary science instruction, I decided to focus on Florida science teaching. Three focus groups were conducted at statewide science teacher meetings. Typically, many of the teachers who attend these meetings are searching for successful teaching methods and innovative ideas to take back to their classrooms. The first focus group session was held at the annual convention of the Florida Association of Science Teachers on October 18, 2003. The session was published in the convention agenda and was attended by five teachers, four from middle schools and one from high school. The high school teacher and one of the middle school teachers were from the same school district. The second focus group session was held on October 28, 2003 during a week-long meeting of teachers who were invited by the Florida Department of Education to an item review of the Florida Comprehensive Assessment

Test (FCAT) for science. After receiving permission from the meeting leaders, I invited all secondary science teachers at the meeting to participate in a focus group session late one afternoon after we had completed our work with the FCAT item review for the day. Three middle school teachers and three high school teachers, all from different districts, were able to participate in that session. The third focus group session was held on February 3, 2004 at the University of Florida during the annual Junior Science, Engineering, and Humanities Symposium, and only two high school teachers from different districts attended that session. Although I had permission from the symposium director to hold the focus group, it was not included in the agenda received by teachers, and it conflicted with student speaker sessions that some teachers had obligations to attend.

Individual interviews were conducted in Hendry County in May and June 2004 in order to saturate the data, and to compare what the focus group attendees reported with what individual Hendry County teachers reported. Hendry County, a small rural school district in southwest Florida, has a large Hispanic population and many students in poverty, with 75% of all students receiving free or reduced lunch. Hendry County science teachers were invited to participate through personal contact, either e-mail or telephone. The Hendry County participants included three middle school teachers and three high school teachers. All of these teachers were certified to teach science in Florida, and all of them had at least 9 years of science teaching experience, often many more. However, one of the individuals had only four years of science teaching experience in Florida. After these interviews, it became apparent that I needed more input from a reading specialist regarding some claims that local teachers made about reading requirements in their classrooms, so I also interviewed a Hendry County middle school reading specialist who agreed to discuss middle school content area reading problems and concerns. She also taught 6^{th} grade science for four years.

Most of the focus group participants were unknown to me before the interviews, and they viewed me as a fellow teacher with some knowledge of using reading to teach science. All of the individual interviewees have known me as a teacher leader and science department chair in my district for many years.

Ethical Considerations

Prior to data collection, I gained approval from the Institutional Review Board at the University of Central Florida. All participants were provided with a written consent form, which they voluntary signed, retaining one copy for their records. There was no compensation provided for the participants. The focus groups were conducted in comfortable meeting rooms, while the individual interviews were conducted at convenient times in locations of the interviewees' choice, usually a school classroom or office, but in one instance the interview was conducted in my home. During all the sessions, the participants were treated with respect and courtesy. The participants were promised anonymity, and I have the audiotapes and transcripts stored safely. For ease of discussion of results, I have assigned numbers to the teachers.

Data Collection Techniques

Data gathering was accomplished through open-ended focus groups and individual interviews. To ensure rigor, a purposeful sample of experienced secondary science teachers was selected to give information about how they incorporate reading in the science curriculum. Focus groups provide data from the group interactions that occur during the interviews, exposing similarities and differences of participants' experiences (Morgan, 1997). During the interviews, I wrote brief notes that were helpful when transcribing the interviews. All of the interviews were audiotaped and transcribed word-for-word by me as soon after the interviews as possible, then I validated my transcriptions against the original tapes. As I worked to analyze the data, I printed different copies of the transcriptions so that I could highlight different information to help me induce the connections teachers make between reading and science in their classrooms.

Data Analysis

According to Morgan (1997), focus groups have an advantage over individual interviews if the topic under discussion is one that participants find routine or "not thought out in detail." Additionally, in grounded theory, focus groups contribute to theoretical sampling and allow comparisons to be made among the participants. A significant topic is one that is mentioned by many people in different focus groups, or one that is met with enthusiasm (Osborne & Collins, 2001). Since I conducted focus group sessions as well as individual interviews, I hoped to find similarities in their experiences as I applied grounded theory methodology.

Researcher's Background

I have taught secondary science for 30 years, bringing considerable background knowledge to the field of science education. Since 1980, I have been science department chair at my small rural high school. For the past 20 years, I have been a member of various educational organizations, including the National Science Teachers Association and the Florida Association of Science Teachers, that actively support inquiry learning in the classroom. In the early 1980s, I worked on the original draft of the Florida Sunshine State Standards for science. In 1999, I was recognized as a National Board Certified Teacher in Adolescent and Young Adulthood Science.

After the establishment of the FCAT as a tool for assigning school grades, our school received Cs and one D because of our FCAT reading scores. My school's principal asked me to help launch an instructional focus calendar at our school. The purpose of the calendar was to ensure that all teachers teach specific reading skills during each week, but it was met with much resistance from subject area teachers because of the time involved in preparing the lessons, and the belief that the reading lessons did not help cover the science content standards. For the past two years, I have worked as a content reading consultant for *ChemMatters,* a magazine produced by the American Chemical Society. In that role, I have discussed with teachers how they use that and other reading materials in their classrooms, and how they can improve the reading comprehension of their students.

Because of my science teaching experience and my prior knowledge of the expertise of some of the teachers interviewed, I attempted to avoid preconceived opinions about the data. In order to preclude finding what I expected, I conducted semi-structured focus groups and transcribed the interviews verbatim, thus allowing the teachers to speak for themselves in the discussion. I sought not to impose my views into their conversations as I explored how teachers integrate content reading instruction with scientific inquiry to promote scientific literacy of their students.

CHAPTER FOUR: RESULTS

The purpose of this study was to describe how secondary science teachers report addressing scientific literacy acquisition of their students by teaching content area reading strategies to learn scientific concepts, and teaching for understanding the processes of science using an inquiry approach. I used a qualitative approach, specifically grounded theory, to the problem because that allowed me to develop a theoretical model (see Figure 1) that may be useful to secondary science teachers who want to enhance their science instruction by combining content reading strategies with scientific inquiry.

Data Analysis

During the data analysis phase of this project, I applied grounded theory methodology as first described by Glaser and Strauss (1967). As I explain each stage of the data analysis, I will illustrate how grounded theory was used to interpret the data. After transcribing each of the interviews verbatim, I read the documents and highlighted statements about reading and science that were relevant to my study, omitting information about reading classes and class discussions that some teachers described because they did not apply to my study. I then made preliminary margin notes (memos) in preparation for open coding. The first level codes were generated from the interview data. For example, the statement, "Students focus on words, not ideas" led to the first level code, *reading problems*. Statements as diverse as "All teachers should teach reading" and "Language arts teachers should teach reading" were included in the first level code, *teacher beliefs*. All of the teachers described *school-wide initiatives* such as *Accelerated Reader* in middle schools, instructional focus calendars, *Navigating Life Through Literacy*, and silent sustained reading. The first level codes are listed in Appendix D.

Next, the source of the information (focus group interview or individual interview) was entered into an Excel spreadsheet, along with the first level code and details from each interview. I left a blank column in the Excel document for adding additional memos. This aided me later on as I worked to analyze the data because it allowed me to sort according to codes or source of information.

After examining the first level codes, I re-printed the interview transcriptions so that the information was fresh and not prejudiced by my initial reactions to the data. I re-examined all of the interview data to look for emergence of core categories using the constant comparative method (Glaser & Strauss, 1967). This included comparing data and integrating categories. I searched for relationships among categories using axial coding to identify the central phenomenon and the categories relating to it (Creswell, 1998). The first-level codes were collapsed into five core categories (see Figure 1). The core categories represent the causal conditions (*Influencers*), context (*Issues*), intervening conditions (*Perceptions*), implementation strategies (*Class Routines*) and consequences (*Future Needs*) that affect the inclusion of reading in science instruction. From this, *Instructional Modifications* was identified as the central phenomenon because teachers often described pragmatic and philosophical changes in their teaching as they deliberated to meet state standards in both science and reading.

To facilitate triangulation of the data (Anfara, Brown, & Mangione, 2002), I prepared a matrix listing the core categories and matching the first level codes with the source of the data, focus groups or individual interviews (see Appendix E). Because it seemed that there was a difference in the perceptions of the individuals interviewed and the focus group participants, I decided to analyze their responses separately, then compare the data for a more complete understanding of each core category and the central phenomenon. What follows is a separate analysis of each category, followed by a summary.

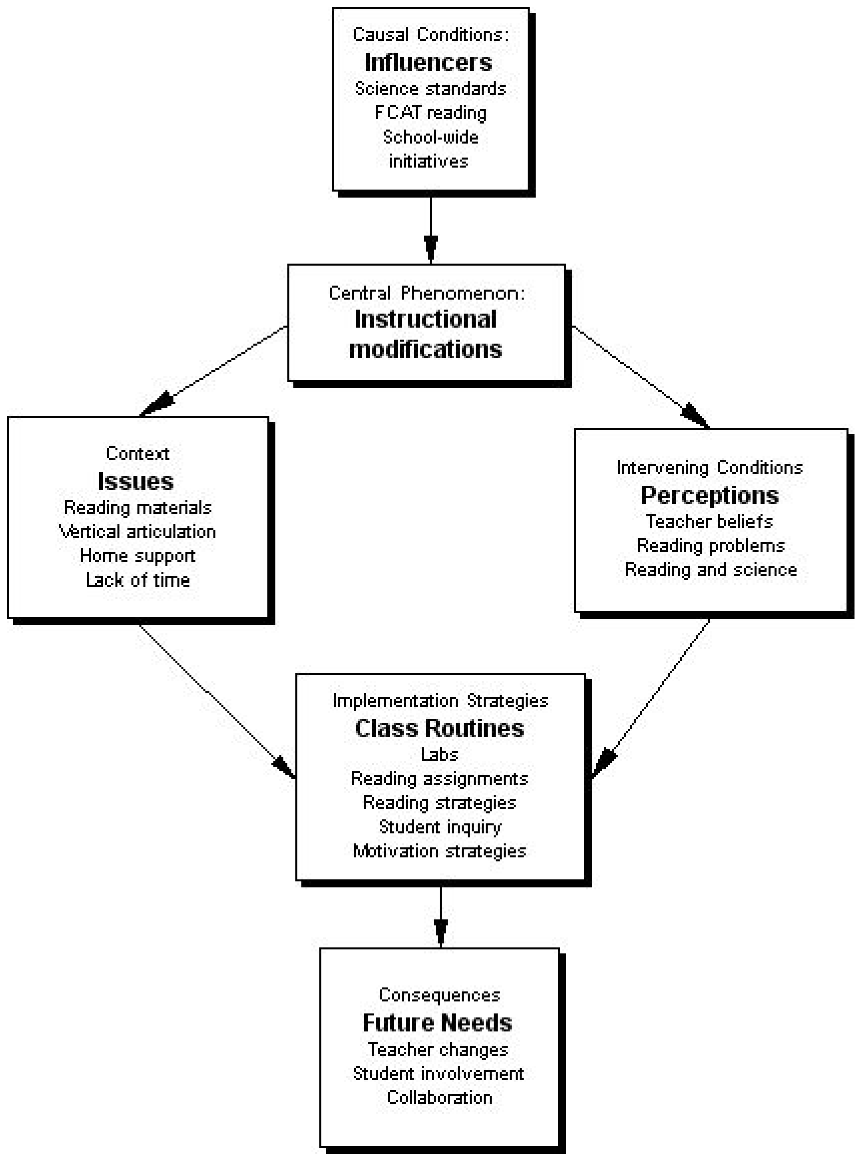

Figure 1: Theoretical Model

Causal Conditions

Influencers

The causal conditions were in the category Influencers. This category included mandates outside the school's or school district's control such as Florida's Sunshine State Standards, and FCAT testing in reading, math, and science. Also included in the Influencers category were district and school-wide initiatives such as implementing instructional focus calendars and mandating professional development in reading in the content area for all teachers. Influencers over which the teachers exerted more control were textbook choice and use of the Internet for reading in the classroom.

Focus Groups

The science teacher discussants felt an obligation to teach science content so their students would be successful on the science FCAT. Teacher 9 lamented, "We're trying to cover everything. Such great breadth, and no depth. If we were to go deeper, and had the time to go deeper, I think our students would be more adept at reading." Teacher 7 added, "I think that our standardized testing has caused a big problem there because we are feeling so pressured to get across so much content." This problem was exacerbated because elementary teachers were so focused on reading and math that they're not teaching content-area reading to their students. The teachers in this focus group agreed that elementary teachers ought to use more informational, as opposed to literary, text. Teacher 12 prepared her own weekly assignment handouts for the textbook correlated to the Florida Sunshine State Science Standards and benchmarks. She stated bluntly, "Teach to the test is our content area. No problem there because I teach to the test."

All teachers had attended some type of professional development such as Project CRISS training (Santa et al., 1996) or MCREL training based on *Teaching Reading in the Content Area: If Not Me, Then Who?* (Billmeyer & Barton, 1998). Teacher 7 highly recommended the MCREL training, saying, "It's excellent, very research-based, and very teacher friendly." In spite of these professional development efforts, one teacher said, "Teachers don't really know how to instruct kids in how to read, a lot of teachers just take it for granted kids . . . know how to do this. We don't really have the strategies. That's why in our county we've taken it on as a mission to help teachers know how to teach reading graphics and reading diagrams and using the resource tools." Later on, a teacher from the same district said that in her district a module for teaching science teachers how to teach reading had been developed by a science teacher and another teacher. "And it gives us a common language, common tools, strategies . . . wonderful resource." Another teacher in the same focus group pointed out that it was important that a science teacher had been asked to help produce the reading resource because sometimes the subject area teachers are overlooked in the development of reading resources.

School-wide initiatives were described by many focus group participants. One middle school teacher complained about the time involved in planning for the mandated curriculum, and the content did not fit her science curriculum. Another teacher in the same focus group stated that she believes she taught 20% less science content because of the school-wide constant improvement initiative at her school, and she resented it. In a different focus group, one teacher said that each week they have a 30-minute silent sustained reading period at her school, where everyone, teachers included, read silently. She said that her students enjoyed the old science-related magazines, including *Discover*, *National Geographic*, and *Outside Magazine* she brings to class for them to read.

Almost all teachers agreed that the textbook readability was too high for their students but they felt powerless to choose other textbooks because of the science content they must include in their instruction. Teacher 19 asked her administration to order a textbook at a lower level because she felt that she was losing 70% of her classes, but after being turned down, she found ". . . worksheets that are actually lower level. My hope is to start them out lower and build them up to a point." Teachers attempted to use the chapter structure of textbooks to advantage, but the flow from chapter to chapter hampered some teachers. Teacher 13 said that he teaches chemistry in a different order than the textbook because "I think the kids learn it easier the way that I teach it." He also used different sections of the book such as readings about the history of chemistry or different people in an attempt to help students connect to chemistry. Teacher 8 complained about textbook structure: "It jumps around . . . so much detail here, and then all of a sudden you go to fact and opinion, then you go to cause and effect."

Hendry County

Hendry County teachers were under the same statewide mandates as the other teachers, but the school initiatives were different. At Hendry County middle schools, all teachers were required to teach one reading class during the day. In addition, they were obligated to support their schools' *Accelerated Reader* (AR) program. Teacher 1 said that "some of the boys sometimes read animal books" for AR, then she added, " They can read these AR books, but they can't read the science book, because it's a different format altogether." Teacher 4 complained about AR, saying "When these kids are reading for enjoyment, they should pretty much be able to read what they want, instead of always having to be at this certain level." He thought that students would read more science books if they didn't have to worry about meeting their AR goals. Teacher 5 disagreed, saying that the reading levels are usually higher in science books, but the students only get a half point because they are short. Teacher 5 read one AR book to her science classes each nine weeks, then made allowances, if necessary, for them to take the AR test to help them meet their AR goals. The middle school reading specialist said that the teachers were mistaken in their beliefs because "Most of the nonfiction books are higher level reading even though they're shorter in number of pages. They're higher level because they contain so much more information."

The high school teachers interviewed did not directly mention the instructional focus calendar school-wide initiative because they knew that I was aware of the program. As they discussed inclusion of reading in their science classrooms, the assumption was that I knew they had to address the reading benchmarks on the instructional focus calendar for their school as well as science standards.

Hendry County middle school teachers chose textbooks based on their correlations to Florida's Sunshine State Science Standards and the availability of ancillary materials that support the FCAT. The publisher also provided a crossword puzzle maker and a test bank. At both middle schools in Hendry County, the textbook publisher annually provided FCAT multiple choice practice questions that teachers may use for each chapter. Teacher 5 described these as promoting "critical thinking skills."

For these, students read a passage, then answer questions based on the reading. Some teachers believed that students would be given passages to read for comprehension on the science test, but that was not the case. When I asked Teacher 1 if the FCAT questions provided by the textbook company were like FCAT science or FCAT reading questions, she answered, “Most of it’s related to content . . . stuff right out of the chapter.” She allowed the students to use their textbooks for these practice questions, so that made it similar to FCAT reading but not FCAT science. She did not enjoy using the FCAT materials with her students because “the kids are so turned off by it.” Teacher 5 allowed students to use their textbooks for the assessments, claiming that that is more “FCAT-like.” Teacher 4 used the FCAT practice test provided by the science textbook for every chapter he taught, but he noted that some of it was like FCAT reading or FCAT math test, not the FCAT science test, because “You have to do a reading, then go back and answer the questions which would be based on the reading over here.” Teacher 4 assigned questions from the textbook every day, with his goal being to complete a section each day. Teacher 5 said the textbook is “very difficult for 7^{th} and 8^{th} grade.” Later on, she added, “I use the textbook a lot for information. They have to know how to find information.”

Teacher 3 chose the textbook for the usefulness of the ancillary materials, especially the teacher notes that help bring the science to life. Teacher 6 complained that “There is a lag time between what teachers need and when it is prepared by the textbook companies,” so he frequently supplemented the textbook with materials he created to teach current, high-interest scientific topics. Although Teacher 2 had textbooks for her students, she did not assign reading in each chapter she taught; however, she reported, “There are certain sections that we look at in depth.” Middle school Teacher 1 enjoyed using the hands-on activities that are in the middle school textbook.

Hendry County teachers reported division of the applicable science standards among the grade levels, but communication among high school and middle school teachers did not lead to high-quality or consistent vertical articulation. Therefore, Hendry County students might have found the instruction repetitive as they progressed through different grades.

Influencers Summary

None of the teachers mentioned the federal No Child Left Behind Act or the *National Science Education Standards* (NRC, 1996), indicating that they were more focused on meeting state standards than national standards. All of the teachers who participated in the study were working to include Florida’s science standards as well as reading standards in their instruction, largely because of the influence of the science and reading FCAT, but many were unsure of the difference between skills students need for the reading portion of the FCAT compared to the science portion. The science test required students to add new information when interpreting a graph, chart, or reading passage, while the reading test required that the students infer their answers based solely on the information given. Overwhelmingly, the textbook was the biggest influence on curriculum for both focus group teachers and Hendry County teachers, but teachers in both groups used only the chapters correlated to the science Sunshine State Standards they were assigned to teach. All of the teachers reported implementation of school-wide initiatives that emphasized FCAT reading success. In Hendry County, the required

Accelerated Reader (AR) program exerted a huge influence on instruction in middle schools, but that was not mentioned by any focus group members. In the AR program, students' grades were linked to earning a certain number of points by reading books at or above their reading levels. After reading each book, students took a multiple choice test on a computer to demonstrate comprehension of the book.

Most often, the content reading professional development offered by districts was CRISS strategies, but some districts offered MCREL Reading in the Content Area. One county had professional development that encouraged cross-curricular integration at the middle school level. Hendry County teachers did not report cross-curricular integration or vertical integration within the district or schools that the focus group teachers did, perhaps because they knew that I was aware of mostly unsuccessful attempts at implementation.

Central Phenomenon

Instructional Modifications

The causal conditions led teachers to make changes in their instruction after examining the issues that relate science and reading as well as their perceptions about how to improve student reading skills while providing quality science instruction. Without the influence of state standards, the push to improve FCAT reading scores, incentives for professional development, and information regarding school-wide initiatives, many teachers would not have felt the need to change their science instruction. Teachers have added more reading opportunities to their classes and most of them searched actively for cross-curricular activities and projects to involve their students in learning. The standards have been a positive influence, causing teachers to be more reflective about their teaching.

Focus Groups

Many teachers described changes they have made to their curricula. For some, it was “an epiphany,” as middle school Teacher 10 said, “It’s not only the reading teacher’s responsibility, but it’s all subject areas.” Teacher 7 agreed, saying “I felt . . . the text was a tool, and I soon learned that the kids need that tool . . . they are really not able to do this. What can I do to help them?” Teacher 8 added, “I don’t think of teaching reading any more . . . I think that teaching science is so much a foreign language to some students anyway that what you’re teaching is a foreign language through reading it [science]. I don’t see it as anything that’s really separate.”

In the focus groups, teachers reported that many reading strategies work well for learning science as well as reading. For example, Teacher 8 claimed that KWL is just part of teaching science, and free-form mapping is a “very dynamic strategy for learners to be engaged.” Teacher 9 added, “Now it’s all kind of mixed in,” and even teachers who formerly avoided teaching reading now see the advantages of using reading strategies such as those taught in CRISS professional development. Two focus group teachers, Teacher 15, who taught AP students, and Teacher 19, who taught low-level middle school students, endorsed linking science vocabulary to Spanish words because of their Latin roots. Another reading strategy that was enthusiastically endorsed by those focus group members who have seen it was Foldables, three-dimensional graphic organizers developed by Dinah Zike (1992). Teachers who used Foldables to help students learn new vocabulary words found the strategy to be hands-on while it encouraged student creativity and motivated students to try something new.

Teacher 10 came to the realization that teaching reading is not only the reading teacher's responsibility, so she gave up lecturing to her middle school students in favor of helping them read and understand the textbook. Teacher 16 noted, "When you read science, you read in a certain way," so science teachers must teach that, and she tried to include more reading opportunities. At Teacher 14's middle school, they implemented cross-curricular planning so that student reading was related to science projects they were working on. They read scientific papers, then they found their textbook easier to understand.

Hendry County

Teacher 3 claimed that KWL charts were a good method for addressing student misconceptions prior to instruction as well as to determine what students thought they knew as they made connections with reading science and their everyday lives. He also taught students to look for prefixes and root words to learn new vocabulary. Teacher 5 ordered science trade books, paperbacks that focused on single issues such as viruses, to use with her middle school students because they were high-interest, they related to the standards, and they came with critical thinking questions and activities.

Instructional Modifications Summary

Most of the teachers interviewed were positive about the influence that reading initiatives have had on their science instruction, and they were enthusiastic about some of the new reading strategies they have taught their students. They cited the usefulness of KWL charts to determine students' prior knowledge, and teaching students to look for root words to make connections to other languages or topics. Yet, a few Hendry County teachers did not report making significant or lasting changes, with Teacher 1 claiming that "FCAT de-motivates students." This reluctance to change, in spite of the influencers, was seen as significant because it represents a failure to convince the teachers of the value of change.

Context

Issues

The category Issues described the context or specific conditions affecting the central phenomenon. Context issues included problems teachers face such as limited access to reading materials other than the textbook and inadequate time to prepare. Other issues included lack of students' prior scientific knowledge because of the emphasis on reading and math in the elementary schools in Florida, and home support of reading.

Focus Groups

Teachers mentioned a "time crunch," needing more time to work with other teachers to develop curriculum, and more time with students. In one focus group, Teacher 10 said, "I feel as if the reading is taking away from the things that we can be engaging in, doing the lab experiments." This was repeated by other teachers in the focus group who must meet criteria for school-wide initiatives to improve reading scores. Teacher 13 recognized, "You can't just present it and say, well, they got it." A less-experienced teacher in Focus Group 1 said, “That’s [correlating resources for a grade-level unit] a lot of pressure and stress on me and then they have to perform on the FCAT . . . ” Later on, she said “I have to, kind of like, adjust my way of thinking and my tools that I have for teaching in order to make it conducive to the reading environment as well as content in the labs and everything.” These comments directly related to the central phenomenon of instructional modifications.

Teachers were not the only ones pressed for time. Teacher 13 pointed out, “One of the biggest problems you get with high school students is that they really don’t have time to read everything like they should.”

In addition, at some middle schools, teachers were voluntarily working together to develop cross-curricular units that try “to get them to think a lot more about science while they’re reading.” That included reading novels as well as scientific papers that relate to what they are studying and writing research papers about in science. In one school district, teachers were in the process of developing curriculum maps and calendars that took advantage of vertical articulation among grade levels. These tools prescribed what science content should be taught as well as when it should be taught. Teacher 9 felt it was important to collaborate with other teachers who were teaching the same things.

Hendry County

In an effort to encourage his students to read more, Teacher 4 recently started using *Science World* magazines in his class. After a test, the students read the article in the magazine that had multiple choice questions included, then they sometimes read any other article in the magazine they wanted to, or they read something else altogether.

Teacher 5 liked having a class set of trade books in her class because they were very high interest, they included excellent teacher resources, and they were a “quick fix” for her, making sure she was “hitting the right things at the right grade level.”

Teacher 3 used the example of “force” as a term that gives students trouble in science because it is used differently in casual speech. He said, “They’re not real sure what force is. Sometimes they . . . confuse that with pressure, for example.” Other physics concepts also gave students trouble, he claimed, and they could not understand the concepts just by reading the textbook; they needed hands-on activities. He added, “Sometimes they can parrot the words back, but if you change a couple words in a sentence to try to see if they understand the concept that’s being presented, oftentimes they’re lost at that point.” Teacher 4 agreed saying, “The students don’t know how to apply what you’ve gone over, or what you’ve taught, to maybe a different situation.”

Teacher 2 and Teacher 3 emphasized that students need a lot of reading support at home. Teacher 3 blamed the environment for students’ poor vocabulary, saying “There’s a resistance to learning a little bit more complicated words.” Teacher 5 agreed.

Issues Summary

Lack of time to teach both reading and science was a universal theme. Vertical articulation and cross-curricular planning was also hampered by the inability to find common planning time. Teachers felt that many available reading materials supported their curricular goals, but they would like more and better materials that are correlated to the reading and science standards. No ideas about improving home support were given, but teachers recognized that students must be encouraged to read at home, too.

Intervening Conditions

Perceptions

The Perceptions category included reading problems that all students have, as well as teacher beliefs about how to address teaching reading and science. Science teachers expressed different beliefs regarding literacy than other content area teachers, and these beliefs were influenced by their beliefs about their subject matter and their students (Readence et al., 1998). Further, science teachers' literacy practices varied from teacher to teacher.

Focus Groups

While some teachers said they believed that reading teachers, not science teachers, should teach reading, most agreed "All teachers are reading teachers." They recognized that each discipline has its own peculiarities regarding reading that should be addressed by the teacher. Teacher 12 said, "There's that misconception, I think, that science teachers don't do reading well." Teacher 13, in the same focus group, agreed saying, "If you do science well, you have to do reading well." Another teacher cautioned that if middle students are given reading assignments every day, "They start to hate reading, and start hating science, too."

The focus group teachers lamented students' poor reading abilities and limited student vocabulary, both general and scientific. Teacher 16 summed up many teachers' observations, noting "Students read words, they do not read thoughts . . . They can read the words, but not with comprehension." Teacher 15, who taught advanced biology students, pointed out, "Even bright students have problems reading science." In science, students frequently had problems because vocabulary words often have different or more specific meanings than they do in everyday speech or literary text. All teachers believed that specialized science vocabulary presents special problems for students. One problem was that words they already know have different meanings in science, such as the word “mole” in chemistry.

Hendry County

Hendry County’s issues were very similar to those of the focus groups. Teacher 6 claimed that all teachers need to teach reading, recognizing that science had different goals for understanding because students needed to not only understand the objective, but also process the information. Teacher 2 said, “I have so much to cover, and I don’t have time [for students to go to the library]. I would definitely lose out on some of the standards if I did.” Her class was teacher-centered, “I have to explain everything to them, I have to teach them, I have to go over and over it with them.” Teacher 1 admitted she should probably spend more time on reading, but she was so content focused, she doesn’t make time for reading. Teacher 5 acknowledged, “There’s a lot of reading in science.” The middle school reading specialist lamented, “Most of the curriculum teachers . . . that I’ve worked with, view reading as a problem by itself and it’s not their problem to teach reading in the classroom so that their students can get a better grip on their curriculum . . . They’re not responsible to teach the students to read.”

Teacher 6 had been teaching for 33 years, and “without a doubt” he had seen a decline in student reading levels. He cited some of their reading problems as lack of fluency and poor critical thinking skills. Teacher 2 found that her 11th grade students are much better readers than the 9^{th} grade students, perhaps because so many students dropped out between 9^{th} and 11^{th} grade. She had students who ". . . struggle word for word. The simplest words that you take for granted, they don't know how to pronounce, or what they mean." Teacher 5 did not think that students were reading at grade level when they came to her, and a lot of them were not at grade level when they leave, although they showed improvement. "I'm not a miracle worker," she stated, adding that classes differed from year to year. Another middle school teacher, Teacher 1, said "They have a hard time reading the science book, especially the lower level kids." Later she added, "Vocabulary. . . They have a hard time with the words." Teacher 4 stated that most students have "pretty low vocabulary," but some surprise him with their exceptional word knowledge.

Teacher 3 claimed that connections to their daily lives were important in order to help students become better readers. When his students were doing research, he encouraged them to talk to a family member who knew something about the topic first, like a grandmother who raised roses, or something like that. Some even had an alligator farm. Then he led them to read more about the topic in the library or on the Internet. Teacher 5 also emphasized parent involvement in her classroom projects. Most of the applications Teacher 4 described did not involve reading; instead he asked questions and gave a brief answer, hoping students would find out more information on their own. He told them, "Well, research it, see what you think. I don't know all the answers either." His students did bring in current events articles on their own for class discussions.

Teacher 5 stated that her students are excited about science when they arrived in her 8^{th} grade classroom in the fall. Teacher 2 looked for articles that related science to sports or other applications that interested students but she usually summarized the articles orally for them instead of encouraging students to read them on their own.

Teacher 1 and Teacher 3 were not afraid for their students to see them as learners, they readily admitted when they did not know the answer to student questions. Yager (2004) claimed, “The best teachers are involved learners” (p. 415).

Perceptions Summary

Most teachers in both groups claimed to be “autocratic” (Teacher 12) or “teacher-centered” as well as content-focused. Furthermore, they realized that they need to teach reading as well as science, and they actively sought ways to include reading in their curriculum. Although the teachers recognized that many students have reading difficulties, they did not report how they addressed individual student problems. Only one teacher reported looking up her students’ FCAT reading scores or other indications of students’ prior reading knowledge to guide her instruction. None of the teachers described connecting reading and science process skills.

Implementation Strategies

Class Routines

The Class Routines category described the implementation of strategies for reading in the science classroom. This category addressed issues that teachers can have an effect on, such as providing reading activities that engage students, helping students apply the knowledge they gain through reading, and encouraging student reflection. Some of the details mentioned by teachers in this category, however, were in large part under the students' control, including motivation, setting priorities, and taking responsibility for reading. Teachers have introduced class routines and procedures that addressed the need to involve students in the learning process and help students make science and reading connections. Students were asked to complete textbook reading assignments, projects, and labs. Strategies teachers employed to help students become better readers of science text included oral reading, teacher-made materials to complement the textbook, CRISS and other reading in the content area strategies, journaling, special attention to difficult science vocabulary, and assessments that contained a reading component.

Focus Groups

Many teachers required students to read the information prior to the class presentation, echoing the opinion of Teacher 13: "There's no use for me to talk to you about it until you've read it." Teacher 12 emphasized that repetition is how students learn science, stating emphatically, "So, now they have done the homework, they've heard it in class, they've had to write the terms, so that by the time we get to the assessment portion it's not the first time they've ever heard it."

Reading in class was addressed differently according to the goals of the teacher. Teacher 19 encouraged her students to read aloud in class saying, "Everyone learns together. The vocabulary words were new for all." Teacher 11 used "popcorn reading" where students take turns reading and call on the next person, but a "pop passover" was allowed so that students would not be embarrassed if they did not want to read. Teacher 10 also said they read out loud to each other; however, most teachers interviewed did not ask students to read aloud because so many students struggled with the words and their fluency was poor. “The other kids get frustrated because it’s taking so long,” said Teacher 17. Teacher 13 enthusiastically endorsed the teacher reading aloud to students because “Kids love it!” He spent five minutes each day reading aloud interesting nonfiction books related to what they are studying.

To aid student understanding and encourage students to read on their own, some teachers found opportunities for application, such as Teacher 9 who used problem-based learning in her classroom. This observation was supported by Wilhelm et al. (2001), who cautioned that “only by first understanding the text can we then meaningfully reject or embrace its meaning” (p. 73). They further argued that reading is best taught through problem-based learning in a context of inquiry. Teacher 7 pointed out that “Students are always using process skills, like classifying, organizing data, looking for cause and effect . . . Those are good reading strategies, too.” Teacher 12 began each class with a journal entry that required students to respond coherently to something she assigned. She claimed, “Normally, 4 out of 5 of those is some type of reading. The reading can be out of the book, it can be an article.” Reading and writing complement each other (Topping & McManus, 2002).

Most teachers provided step-by-step procedures for laboratory work, but they varied in how much reading students had to do to follow the steps. Teacher 12 said, “We’ve taken reading out of the lab, we’ve replaced it with writing the lab report.” She claimed, “When I gave them the paper [procedure], they didn’t get the process.” Other teachers who use step-by-step procedures often assign a prelab assessment, which varies from the 5-point quiz used by Teacher 15 to the questions sheet assigned by Teacher 13, who said, “ ‘Ready to do the lab’ means you have read the material, you understand what we’re going to do, and . . . you’re ready to go.” Many teachers agreed with Teacher 8 who said, “The labs are usually written fairly distinctly and straightforward . . . I think that determining meaning from text is their problem.”

Most of the motivational ideas that integrated science and reading related to students’ lives, such as service learning, problem-based learning, and contests like the Envirothon, where students competed at the local, state, and national level after in-depth study of environmental issues. Three teachers enthusiastically endorsed using science fiction to reinforce science concepts while engaging students. Only two teachers mentioned anticipatory activities, and they were discussions prior to reading, in order to give students a purpose for reading.

Students used the Internet as well as the library for student research reports. Teacher 13 and Teacher 19 required projects such as science fair or written projects that applied to their lives. Teachers encouraged students to use technology to integrate reading and writing with what they learned. For example, Teacher 13 assigned a trifold paper (brochure) about an element. He claimed that, “They have to do a lot of reading in order to do that like I want it.”

Teachers described a wide variety of reading strategies, but the most popular were KWL, Venn diagrams, and jigsawing (see Appendix A). Teacher 8 was the only one who used cloze worksheets. Teacher 13 stressed the strength of using SQ3R (Survey, Question, Read, Recite, Review) as a reading method for learning the technical information in a chemistry textbook. That was the only reading method he taught to his students, but he allowed them to use other methods if they preferred. He required that they use some reading method. He also pointed out that chemistry is based on codes such as the periodic table, and he encouraged his students to look for patterns to simplify their understanding. He said, “I think I teach reading all the time in the sense of teaching the reading of code, because that’s what I’m doing with chemical symbols, when you write those symbols into formulas, then you take those formulas and you put them on out into equations.”

Hendry County

Hendry County teachers frequently used the textbook, but they varied in how it was used. Only Teacher 3 specifically mentioned modeling how to read and think while reading for students, yet this was singled out by the reading specialist interviewed as the most important activity that subject area teachers can do with their students. Teacher 3 began each school year by pointing out the structure of the textbook, including the section objectives, questions at the end of each section to check for understanding, and the glossary. He also encouraged students to look at the diagrams and graphs that accompanied the reading, recognizing as Lemke (2004) points out that science reading is different and students must understand the graphics and equations to make sense of the verbal text. He depended on the text structure for guiding student inquiry and outlining the chapters and sections. Most teachers allowed class time for students to read the textbook silently, then they discussed the information and answered questions from the textbook. Teacher 4 assigned a textbook section with questions each day. Teacher 5 always allowed the students to use the textbook to find answers for assignments and tests because she viewed the textbook as an informational tool, and the students needed to learn how to find information.

No Hendry County teachers interviewed used classroom group reading, yet most had attempted and then discarded the practice because of students' poor reading fluency. Teacher 2 read the textbook "very slowly and clearly" to her ESOL students, and occasionally to other students, explaining things as she progressed through each passage. Teacher 1 played audiotapes provided by the textbook publisher while the students followed along because when she read aloud to the students, some of them did not pay attention since they knew she could not see them while she was reading. Teacher 5 was the only teacher who reported reading interesting nonfiction books aloud to students, discussing it afterward, then allowing the students to take the AR test on that book so that it counted toward their AR goal.

All of the Hendry County teachers routinely addressed vocabulary in their daily instruction. Students' science vocabulary knowledge was poor, according to the teachers. Vocabulary improvement was addressed in several ways. Teacher 3 used the Frayer model (Billmeyer & Barton, 1998) which is a large rectangle divided into fourths with the word in the middle. Usually students wrote the definition of the word in one quadrant, characteristics or facts about the concept in a second quadrant, examples in a third quadrant, and non-examples in the last quadrant, but this was sometimes modified depending on what the teacher (or student) believed was important to learn about the concept. Teacher 3 found that "dissecting" some science into root words, prefixes and suffixes was very helpful to students, especially those who spoke Spanish. Teacher 4 included vocabulary words in the notes he gave the students, giving students the definition and an example of how the word would be used in the chapter they were studying.

Hendry County teachers were enthusiastic about including labs and other hands-on activities in their instruction, giving their students step-by-step procedures. Teacher 5 described it well: “They need to be able to read the lab and comprehend what the lab is telling them to do, in the step by step process that it happens.” Since Teacher 1, Teacher 2, and Teacher 4 explained the procedure prior to doing the lab, students could often avoid reading the steps. Teacher 1 explained the procedure before handing out the lab guide sheets to her students. In addition to step-by-step labs, Teacher 1 sometimes assigned labs where students build things, and she let them use their imagination without reading or writing their results. Teacher 3 gave minimal instruction, assuming the students could read the procedure on their own. Teacher 3 was also alert to student questions and tangents they might take during a lab, and had files with further information for curious students. After practice with step-by-step labs, Teacher 5 eventually attempted to make the labs like a mini-science project, all inquiry, with little student reading involved unless the students search for information to corroborate what they have found out. Teacher 6 also encouraged learning by discovery through research or experimentation.

All Hendry County teachers have had CRISS training so that they know how to use reading strategies with their students, but they vary widely in how much they apply the research in their instruction, with two of the six teachers not using the strategies at all in their classrooms. One of these teachers said, “I basically just ask them to read it, then go ahead and answer any questions on their own.” The others reported using some form of a KWL chart that students fill in during the unit indicating what they know, what they expect or want to know at the end of the unit, and finally what they have learned. Teacher 3 found this strategy very helpful for determining students' prior knowledge and uncovering misconceptions students bring to major conceptual topics such as genetics. Teacher 3 also used compare and contrast reading strategies. Teacher 1 uses two-column notes often (see Appendix A). Teacher 5 enthusiastically endorsed jigsawing because it allowed the students to physically move around the room while they taught each other.

All but two Hendry County teachers gave their students outlines of each chapter to guide their understanding. For example, Teacher 4 prepared a rudimentary outline for students, telling them that he has given them only highlights and they need to "go back and read on their own." All of the assignments he gave students were in the textbook or the ancillary materials provided by the textbook publisher. Teacher 2 had the notes, including key words and main concepts, on the board each day, and the students copied them while she completed housekeeping activities. Teacher 1 provided guide sheets she made for the first time students read the chapter, then after class discussion she assigned questions from the textbook.

Teacher 3 often modeled how to find answers to his students, especially at the beginning of the year, and he tried to always give them a purpose for reading. He encouraged students to read everything they can, saying "It doesn't matter what you read, as long as you're reading, your reading skills are getting better." Teacher 3 linked inquiry to reading, saying, "When they read something in the text that they want to know more about, I think once you have the stimulation provided, then I guess reading becomes inquiry . . . There's a purpose to their reading . . . Certainly once you get off on a tangent, then it [reading] becomes inquiry.” He also modeled for students how to do science projects where students have to be able to read and inquire about their research topic.

All but two of the Hendry County teachers assigned research projects to their students, encouraging them to use the library and the Internet to find information about the topics they chose. Students in Teacher 3’s classroom chose a live animal to care for, but before he approved the student’s choice, the student was required to read the catalog where they might purchase the animal, then consult at least three references to find out “how to care for the animal, food requirements, light, and everything else to sustain life. Then they have to synthesize the information and put it together into a report for me to convince me they can take care of the organism.” Just last year, Teacher 4 assigned a project about space exploration to his students. He was very enthusiastic about what many of the students produced, but he realized he would have to provide many more guidelines if he assigns projects in the future because of the plagiarism and wide variance in quality of the projects. Teacher 1 had the advantage of a classroom set of computers for her students to access the Internet to find background research as they began their science fair projects this past year.

Among the unique class routines implemented by Hendry County teachers is the “question of the day” that Teacher 3 wrote on the board each day; however, usually reading was not involved in answering the question. Teacher 3 and Teacher 6 also periodically assigned topics from the textbook to student teams, then they taught the entire lesson to their peers, finishing with an assessment.

Teacher 5 said, “Students are always reading in my class. When they’re finished with science, they do AR.” Once each 9 weeks grading period, she scheduled a “Read Out” for makeup work and those who don’t have any makeup work read their AR books. Students enjoyed the day because they could bring snacks.

Class Routines Summary

For both focus group and Hendry County teachers, there was an emphasis on using the textbook, with many teachers giving students outlines of each chapter. The labs were teacher-directed, usually requiring students to follow step-by-step directions to find an answer known in advance. Only one teacher reported modeling how to read the textbook for his students, and few teachers mentioned activating prior knowledge or using anticipation strategies. Regular reading assignments outside of the textbook was addressed only through research projects. The most frequently mentioned reading strategies were KWL charts, Venn diagrams, and vocabulary instruction (see Appendix A). For student motivation, teachers depended on student projects, problem-based learning, or other long-term activities.

Consequences

Future Needs

Future needs included modifications teachers wanted to implement in their instruction as well as change that must be realized at the district level such as the necessity for collaboration and vertical articulation with elementary schools. Students also must become more involved in learning science through reading on their own, and this would require projects that motivate students to explore.

Focus Groups

The focus group held at the FCAT Science Validation Committee meeting did not have any specific ideas about future needs, but all focus groups placed importance on vertical articulation with elementary teachers who needed to become more comfortable with science. One Florida district had science teachers involved in developing reading materials and curriculum mapping with input from reading specialists, and this practice was lauded by teachers in that focus group.

In the FAST Conference focus group, Teacher 10 wanted more help correlating the standards to the textbook and the outside reading resources teachers were encouraged to use. Teacher 8 agreed, saying, “I’m getting a little tired of re-doing everything every year,” meaning that she often had to develop new reading strategies for new reading materials. She would like to be able to order science magazines such as *Science World* or *Current Science* for her students, especially if they came with reading strategies for each article. Collaboration and communication with other teachers who were teaching the same things would help all teachers become more aware of what they can do and why, according to Teacher 9 who called for more awareness of “what we do and why we do it,” which she called “self-reflection.”

Students needed to take more responsibility for their own learning, especially once they reach middle school, according to Teacher 9. Teacher 13 emphasized the need for students to learn to use reading skills with technology such as the Internet, which also motivated the students to read.

In one focus group, teachers said that we must teach students test-taking skills because they will have to take many different tests, not just the FCAT, the rest of their lives. They said, “Let’s be straightforward and honest on what we’re testing and how we’re testing,” so that we can help the students prepare for different kinds of tests.

Hendry County

Hendry County teachers were very specific about their particular needs so that they can help students read better in the future. Teacher 2 would like a list of FCAT vocabulary words and Teacher 1 would like a list of reading materials for each topic she teaches. Teacher 3 said, “I would like to know how to be a better teacher of reading . . . to try to figure ways to get students to enjoy reading,” a topic he felt wasn’t covered in his CRISS professional development training. The middle school reading specialist said that all subject area teachers should model how to read informational text for their students using think-aloud strategies (Wilhelm, 2001) so that students could see how successful readers approach text. However, most Hendry County science teachers interviewed did not feel comfortable using this strategy for a variety of reasons, including student behavior problems when the teacher was looking at the text and lack of confidence in their own abilities to use the strategy.

Future Needs Summary

Secondary science teachers recognized that they do not work in a vacuum, so they would like vertical articulation with elementary teachers to support science reading before students reach secondary school. Teachers also perceived a need for more specific reading strategies that correlated with the science content standards, strategies they could learn from collaboration with their peers. That indicated a need for more professional development that provides for ongoing support and teacher practice to develop skills in teaching content reading strategies. Finally, students must take responsibility and become involved, active learners who know when and how to apply the content reading strategies they learn in science class.

Case Studies

To elucidate how my theoretical model would apply to particular teachers in specific situations, I prepared a short case study of two teachers who participated in the focus groups. Their stories follow.

Case Study: Teacher 9

Teacher 9, with 20 years of teaching experience, is a National Board Certified Teacher at an urban science magnet middle school. Although she was trained as an elementary teacher, she has always taught middle school science. She is a teacher leader in her school district, and is currently working toward her Ed.D. in educational leadership. She was a member of the first focus group, held at the FAST conference in Jacksonville.

In her role as a teacher leader, Teacher 9 was very familiar with both the national and state science standards and with school-wide initiatives to improve FCAT reading scores. In addition, she frequently attended and provided professional development related to improving student inquiry, especially science fair projects.

Teacher 9 first approached the inclusion of content reading strategies into her instruction as more work, but she has successfully made the transition and encouraged other teachers to do so. Specific modifications she made in her instruction were to reinforce reading through using newspapers in the classroom, and problem-based learning. She complained that elementary teachers have taught too much literary reading at the expense of informational reading. Teacher 9 used FCAT scores and the FCAT norm-referenced test scores to guide individual student instruction.

Teacher 9 described using several CRISS reading strategies, including KWL, bubble maps, and student created concept maps (see Appendix A). She also encouraged students to do background research in order to produce videos to share with their classmates. Finally, she required students to evaluate their own work, which led students to develop self-reflection as a habit.

Teacher 9 believed that all teachers should be reflective and model that reflection for their students and peers. More collaboration among teachers was needed, according to Teacher 9, as well as vertical articulation with elementary and high schools.

Case Study: Teacher 19

Teacher 19 has 15 years of science teaching experience at a rural middle school. She attended the focus group held at the FCAT Science Item Review session.

Teacher 19 was also aware of the impact of science standards and FCAT reading on science education in Florida, but the only professional development to improve her knowledge of content reading strategies that she reported attending was a half-day of CRISS training.

Teacher 19 taught at a school with a large Hispanic population, so she took advantage of the second language ability of her students to introduce science vocabulary that had Latin roots and was similar to Spanish words. She was very concerned about the achievement of all her students, especially the ESOL students, and believed that they were low-level readers, but she did not report checking their test scores to confirm her suspicions. She estimated that 70% of her students could not read their textbooks, so in order to help them succeed, she developed her own reading materials to aid reading comprehension, some based on textbook reading and others she found from outside reading sources. One classroom practice she engaged in that other teachers in the study did not find effective was oral reading by all students. To encourage student inquiry and scientific literacy, she implemented a class science fair where students had to research to find the answer to a problem of practical importance, such as whether disposable diapers were harmful to the environment.

Teacher 19 did not articulate any specific future needs that would help science teachers integrate scientific inquiry and reading, indicating she may not have viewed the disconnect as a problem. Since the focus group session was held she has attended professional development to learn how to implement action research in her classroom. However, I did not determine the focus of her action research plan.

Summary

Most of the teachers in this study, faced with Florida's high-stakes accountability measures, were focused on science content, not scientific literacy or student inquiry. When science teachers read and put into practice the science standards, they often could not imagine how their students might best learn the science content because the teachers were often concrete learners themselves, positivist thinkers with highly structured classrooms. Studies of elementary teachers have shown that many who use inquiry-based instruction do not often use text. Magnusson and Palinscar (2004) suggested that elementary teachers see a conflict between text-based learning and learning through inquiry. Perhaps secondary science teachers share this belief, so they focused on science content rather than inquiry to help students learn the science standards. It might be difficult for them to imagine how inquiry might be tested on a high-stakes test. Teachers wanted their students to be good readers, not just for the FCAT, but so that they could accomplish their future goals and become lifelong learners.

Teachers tended to view reading and inquiry as entirely different processes, with few if any connections. Whenever I asked about students using inquiry skills, teachers most often discussed how they do labs. Most teachers saw little connection between reading and inquiry, other than the fact that students must know how to read to follow directions in the lab. However, one teacher said, "I think that inquiry and labs and reading all go together…where the kids are inquiring about a question. They're going to have to use reading strategies, like from the Web . . . or from somewhere else where they're having to find out about this question." Teacher 9 added, "The more open-ended questions we ask, then they are more tempted to go out and look for the answers, especially if you have taught them how to find them."

Secondary science teachers in Florida were particularly cognizant of the statewide emphasis on reading and their obligation to include reading in their science instruction, as shown by their willingness to participate in the focus groups and interviews. However, no one mentioned the *National Science Education Standards* (NRC,1996), *Science for All Americans* (Rutherford & Ahlgren, 1990), or the No Child Left Behind Act of 2001, which are all national calls for improving science content, student inquiry, and scientific literacy. Scientific literacy, when it was addressed by teachers, was approached mostly through class discussions, not reading. Newspapers and current events were most often mentioned as ways to include scientific literacy into the curriculum. Many teachers, but not all, used copies of newspapers, magazines, and current events that they found themselves. Teachers realized that students cannot learn secondary science content unless they read science text with comprehension; therefore the focus of instruction was on learning science content, not scientific literacy or student inquiry.

Often during the focus group sessions, participants would take notes or ask for clarification when one teacher had a particularly good reading strategy to share. Collaboration was viewed as an important but scarce luxury, as was time to try out new strategies with students. Most of the teachers were actively looking for reading materials and strategies to facilitate student understanding of science concepts, but they did not want to give up limited class time attempting methods that have not been proven to be successful in science classrooms. Instruction remained very teacher-centered, according to the participants. Many teachers reported that they have no time to incorporate good reading practices, such as providing anticipatory activities prior to learning, or modeling how to read informational text, because of the massive content included in Florida's Sunshine State Standards for science. Overwhelmingly, textbooks were used as the major reading tool in science classrooms, especially in Hendry County, with teachers assigning reading from the textbook, often accompanied by a teacher-prepared outline and worksheets provided by the textbook company.

Notably infrequent in describing science reading instruction were references to modeling explicit reading strategies for students, activating prior student knowledge, or providing anticipatory activities. All of these activities have been shown to improve student reading comprehension and student motivation because students are often unfamiliar with the special skills required to read, interpret, and decode science text (Barton, Heidema, & Jordan, 2002; Daniels & Zemelman, 2004; Shanahan, 2004; Wilhelm et al., 2001). Furthermore, in Illinois, science teachers must now demonstrate their abilities to teach science content as well as reading in science (Shanahan, 2004).

As a final step, I prepared a code map (Anfara, et al., 2002) to ensure that the initial codes, categories, and research questions were in alignment and to document my methodology (see Appendix F). Influences at the state and district level were by far the most important category in determining teachers' willingness and preparation to modify their instructional methods. The issues that affected inclusion of reading in secondary science classrooms were adequate science reading materials, vertical articulation among grade levels, home support, and time not only to plan for reading but also to read in class. As teachers planned instruction, these issues were modified by teacher beliefs about the place of reading in secondary science instruction and reading problems that individual students brought to the classroom. The class routines that teachers reported when discussing the inclusion of reading in science did not include much inquiry, but class routines often included labs. Finally, successful implementation of reading instruction in science classrooms required collaboration among teachers at all levels, from school to district to state, and active participation by students in their own learning.

CHAPTER FIVE: DISCUSSION

Overview

The purpose of this study was to describe the experiences of secondary science teachers in Florida as they have worked to incorporate content area reading instruction and student inquiry in their daily science lessons while promoting the goal of scientific literacy for all students. Since Florida's science teachers have been required for the past eight years to support reading standards for school accountability as well as science standards, I sought to explore their unique insight into successful reading strategies that improved scientific understanding of their students. I hoped to discover best practices that combined student inquiry with reading activities in science classrooms.

Through the use of grounded theory methodology, asking questions in both focus groups and individual interviews, I determined that few if any secondary science teachers in Florida were connecting content reading strategies in their classes to the processes of science, specifically scientific inquiry. Many secondary science teachers felt reluctant to spend time teaching content reading strategies because of the pressure to cover science content, and even fewer saw a relationship between reading and scientific process skills. Some resented that they were being asked to fix what they believe is the failure of the system because the students are poor readers when they arrived at secondary schools. These unexpected findings led me to wonder why these particular teachers had not made the connection between science content reading and scientific literacy, and how secondary science teachers could become convinced of the efficacy of incorporating reading strategies into their inquiry instruction.

Most secondary science teachers in Florida have been involved in professional development activities to learn how to integrate content reading strategies into their daily instruction. Science educators need a detailed description of the connections between science learning and reading and how inquiry learning might relate the two. Research suggests that as science teachers teach, they should explicitly model appropriate reading processes and strategies to improve student understanding of scientific concepts as well as methods of inquiry (Baker, 2004). Students have a natural curiosity about science, and many enjoy reading scientific books and articles of interest to them (Daniels & Zemelman, 2004; Thier, 2002). Science teachers can capitalize on this interest by encouraging and promoting student reading related to their science class. All forms of inquiry require reading skills, from reading laboratory directions to reading for background information when engaging in scientific research. These are authentic tasks that will serve students well as they continue their education and embark on professional careers.

Reading and Inquiry

Inquiry-based instruction may be structured inquiry, guided inquiry, or open inquiry, depending on the goals of the teacher and how much guidance students require to conduct the investigation (Colburn, 2004). In any form of inquiry learning, students confer more value to the information they find on their own, whether it is in the laboratory or in the library. Even historical inquiry through research projects helps students better understand the nature of science (Qian & Alvermann, 2000). When teachers help their students think critically about what they observe in the laboratory and connect their experiences to related reading passages, there will be a greater impact on learning. Yore et al. (2003) express this relationship well:

> Scientific literacy involves the location and comprehension of scientific information, the adoption of a contemporary view of science, the development of informed conceptions, opinions, and beliefs, and the ability to communicate these ideas and persuade others of their veracity. This means that science teaching must clearly establish links among experiences, prior knowledge, associated analogies, and concept labels to demonstrate alternative conceptions, images of the scientific enterprise, canons of evidence, and logic. (p. 878)

Establishing these links can be done through purposeful teaching, including reading strategies, that connects scientific reading and student inquiry. Practicing scientists must read about what came before (Kamil & Bernhardt, 2004), and so must science students. Reading or inquiry alone is insufficient for students to develop deep scientific understanding.

Findings

Even though most secondary science teachers in Florida have been encouraged by their administrators to include reading comprehension in their science instruction since the enactment of the Florida school accountability system that graded schools based on reading, mathematics, and writing scores, the study participants would like more and better methods that specifically incorporate reading and science. Evidence for this included the note taking, sharing, and questions that were asked during the focus group sessions that I conducted. However, there was little or no reporting of classroom activities that integrated science content reading and student inquiry. The participants obviously enjoyed teaching science, considering it an integral part of the secondary curriculum, and they did not want to forfeit valuable classroom time teaching reading if they did not see a direct relationship to science. Most of the teachers interviewed individually still teach as they were taught, using the textbook and direct instruction to "cover the standards." The teachers in the focus groups tended to be more innovative and willing to attempt to use creative reading strategies to help their students become scientifically literate than those teachers in individual interviews. That could be because the type of teachers who attended statewide meetings were more involved in the teaching profession and reading research studies. Also, often during the focus group discussions teachers would brainstorm and keep adding to a question I asked, eagerly sharing strategies that worked for them, whereas that synergy was absent in individual interviews.

Kennedy (1997) hypothesized four reasons why teachers may not incorporate findings from educational research into their practice. The first was that the research is not persuasive or authoritative enough and was limited in scope. The second hypothesis was that teachers do not find the research relevant to their practice because different kinds of classrooms or students were involved. The third hypothesis was that the ideas were not accessible to teachers, either because they were physically or conceptually out of teachers' reach. The final hypothesis was that the educational system resists change, or at least systematic change. Of these four hypotheses, I believe that the final hypothesis may explain why there has not been much movement toward integrating science content reading strategies with student inquiry and scientific literacy. Teacher beliefs, structural constraints on practice, and the proliferation of educational goals contributed to this resistance to change, making educational decisions complicated for teachers. The fourth hypothesis also includes fads that do not contribute to meaningful systematic change, and teachers were wary of spending their time learning teaching practices that will be out of fashion in the next few years. When teachers were satisfied with the status quo and the science achievement of their students, they were unlikely to make modifications to their practice. This was especially true of those who taught honors and advanced placement science courses.

Implications

Professional development in Florida has not been sufficient to change all teachers' beliefs regarding teaching reading in science. Although all of the teachers in this study had attended at least minimal professional development activities to learn how to include content reading strategies in their instruction, few made meaningful changes in their instruction without coercion from their school administration. Further, the teachers in this study did not articulate the belief that reading helps students learn how to do scientific inquiry. "Change occurs only when beliefs are restructured through new understandings and experimentation with new behaviors" (Loucks-Horsley et al., 1998). Professional development would give teachers confidence, according to one focus group teacher, but it must be followed by classroom observations and documentation that the teacher is practicing what she learned in the professional development activity (Loucks-Horsley, et al., 1998).

Also, time to develop new content reading strategies and incorporate them into instruction needs to be provided for teachers to be successful in integrating science and reading. Teachers must have ongoing support and constructive methods to evaluate the adjustments they make as they attempt to integrate reading strategies into the science curriculum. Providing teachers with reading strategies that support the reading materials they use in class would save teachers' time and help convince them of the effectiveness of the materials. In addition to administrative support, teachers need time to collaborate with other science teachers, reflect about their practice, and plan innovative instruction that will engage students in reading. A teacher in the first focus group said, "I think we need to become more aware of what we do and why we do it, and that's, to me, very, very important, to start some reflection." There was little curricular integration in high schools, according to the participants, but there was some cross-curricular integration in middle schools due to more flexible scheduling. Professional development could address the need for more curricular integration among core subjects, if teachers see a necessity to change their practice.

In spite of the push for reading in Florida, in the summer of 2004 the *Just Read, Families!* Website suggested only 10 high school books for summer reading, and only one of them was nonfiction, *Anne Frank: Diary of a Young Girl*. No science books, fiction or nonfiction, were on the list. Since science teachers often know what books are interesting to their students, they ought to be consulted to contribute to widely distributed reading lists so that students and their parents have choices that include interesting science texts.

Aliterate readers can read, but they are reluctant to do so. Beers (2003, p. 279) found that there are four types of aliterate readers: “dormant readers” who do not find time to read; “uncommitted readers” who are not interested in reading; “unmotivated readers” who do not value reading; and “unskilled readers” who find reading very difficult. When science teachers explain and outline text for students, and read the lab instructions for students prior to the lab, they may unwittingly be encouraging aliteracy by eliminating the need for students to read for themselves. Students need both science and reading skills to be successful adults, able to make decisions regarding challenges in personal health and environmental quality, for example. Furthermore, some teachers discussed current events in class by referring to articles they or their students brought to class, so students did not read them. This may also contribute to student aliteracy, or rejection of reading even though they have the ability to read (Beers, 2003), because they do not see a need to read when the teacher will orally tell them or give them notes about what they need to know.

Although many textbook companies claim to stress student inquiry activities and they include reading strategies in teachers’ guides, the textbooks themselves are often comprehensive and difficult for students to understand on their own without guidance from the teacher. Many teachers in my study reported that they must often develop their own reading strategies to use with the textbooks, quite a time-consuming task. Some alternatives to textbooks that would be more interesting to students include current magazines, trade books focused on one topic, newspapers, and teacher-approved Internet web sites. With any of these reading alternatives, however, the teacher must provide guidance through explicit teaching of reading strategies that relate student inquiry to scientific knowledge. Reading strategies already published by Project CRISS, MCREL, and others can help students become active, metacognitive learners when using these materials with direction from their teachers. Authors that have been popular with language arts teachers such as Beers, Buehl, and Wilhelm, have ideas that transfer directly to the science classroom. Changing from a transmissive teacher-centered classroom where the teacher dispenses information to the students to an active student-centered classroom where students develop deep understanding of the "big ideas" in science with the teacher as a guide will require implementation of new teaching and reading strategies. New strategies will be incorporated into daily instruction only when teachers who attempt their use have successful outcomes including active student participation and deeper student understanding.

Limitations

Only a small sample of Florida's secondary science teachers participated in this grounded theory study; therefore, the findings apply only to those teachers and locations. Furthermore, the teachers were self-selected and concerned with improving their practice through conversation with other teachers. Teachers who were uninvolved with curricular change and determining best practices did not choose to participate. This study was a snapshot of what was happening in Florida's secondary science classrooms after almost a decade of teachers being required to meet state reading and science standards.

Recommendations for Further Research

Clearly, there is a need to demonstrate the connections between content reading strategies and inquiry to teachers, because those connections have not yet been made by the secondary science teachers in this study despite evidence that active reading and inquiry support student learning in science. Those secondary science teachers I interviewed were willing to implement reading strategies that work, but they must be convinced of their efficacy. Teachers would like to be persuaded of a strong reading and inquiry relationship before they make time-consuming instructional modifications. Action research implemented by science teachers themselves would be useful to determine how reading strategies are helping students become scientifically literate, especially if teachers were encouraged to share their research with others through informal meetings, conferences, journal articles, or even Internet sites.

Several teachers mentioned reading problems of ESOL students and how they used root words, prefixes, and suffixes to help them understand difficult vocabulary. For Spanish speakers in particular, there are many similarities among science words and Spanish words because of their Latin origins. Another problem is that common English words such as *force*, *work*, *energy*, *power*, *pressure*, and *mole* give students problems when they encounter them in science class because their scientific meanings are specific and different from their everyday use. These examples suggest that if teachers could teach science vocabulary by encouraging student inquiry into word origins, science learning would be enhanced. Magnusson and Palinscar (2004) suggest that vocabulary knowledge may be greatly enhanced through guided inquiry science instruction

Many language arts teachers have already researched some of these reading needs (Beers, 2003; Buehl, 1995; Santa et al., 1996; Topping & McManus, 2002; Wilhelm et al., 2001). These suggested reading strategies, including scaffolding and metacognitive connections, could be adapted by science teachers to improve science instruction. For example, one promising method that might be investigated through action research by science teachers is an "Inquiry Square" (Wilhelm et al., 2001, p. 47-48). The square would help teachers consider how students learn to do something through procedural knowledge (inquiry) and what declarative knowledge (content) it would help students understand. Students could also be taught to make "Hypothesis-Proof Notes" (Santa et al., 1996), which are simply two-column notes with "hypothesis" and "proof" as headings, and space for students to record what they think at the bottom (p. 92-93). In my own classroom I regularly provide anticipation guides prior to reading, model new reading strategies, and provide content frames or encourage mapping to help students find relationships among new words and concepts. The emphasis is on searching for evidence to support scientific claims as students inquire into how we know what we know in science. Further, my students read a variety of science texts from the Internet and science magazines as well as their textbooks. Establishing the value of integrating content reading strategies into meaningful student inquiry is needed so that science teachers will recognize the necessity of promoting literacy in science.

Summary

Florida's secondary science teachers were aware of the need to incorporate reading strategies into their science instruction, but most did not see a connection between reading instruction and scientific inquiry. The results of this dissertation show that science teachers need more information and assistance so that they will include content reading strategies that promote scientific thinking in their daily instruction. While many secondary science teachers have attended professional development workshops to learn about content reading strategies, a more valuable approach would be to attend workshops that specifically address the content reading requirements of secondary science students and teachers. This must be followed with classroom visits, collaboration among teachers, and teacher reflection about the effectiveness of integrating reading strategies with scientific inquiry. The connection between reading strategies and student inquiry has been established by various researchers (Kamil & Bernhardt, 1004; Pratt & Pratt, 2004; Yore, 2004), but that information has not been incorporated into most secondary science instruction. If secondary science teachers were convinced of the efficacy of connecting reading and inquiry activities, students would benefit by becoming better readers in an authentic setting.

APPENDIX A: READING STRATEGIES

Reading strategies

Anticipation guides are based on the important topics in the reading, usually designed by the teacher, and given to students prior to reading. Often the guides consist of statements in the reading passage that the students are asked to agree or disagree with, sometimes giving reasons for their responses.

Cloze tests are generally given for assessment purposes. Words are systematically omitted from reading passages, and students are usually given the words in either multiple choice or matching questions to complete the passages.

Content frames are usually teacher-created charts that students complete, showing the relationships among concepts, and including details from the reading.

Free-form maps are student-created maps consisting of bubbles and lines that link related concepts. They help students visualize relationships, and students often include drawings and symbols that help them remember details and connections among the topics in the reading.

Graphic organizers are pictorial summaries of reading passages that include some of the reading strategies listed here, such as the maps, as well as creatively drawn and illustrated diagrams that students complete while they read.

Jigsawing is a strategy used for long reading passages, or even entire chapters. Students are divided into groups and assigned a passage to read and discuss with others who read the same passage to ensure that they have deep understanding so that they become "experts" on that passage. Then, students report to a second group where others have read different passages. In the second group, each student reports about the passage he is an "expert" on, so that all students become knowledgeable about the longer passage.

KWL is a strategy introduced at the beginning of a conceptual unit. Students draw a chart with the headings "Know," "Want to Know," and "Learned." Before any instruction or student investigation, students complete the "Know" column. After a student engagement activity, students complete the "Want to Know" column, then at the end of the unit they finish the "Learned" column.

SQ3R (Survey-Question-Read-Recite-Review) is a reading strategy used by students. First, they survey the reading passage prior to reading to think about what they already know, then they think of questions to guide their reading. Next, they read actively to find answers for their questions, then recite answers or recall what they read without looking at the passage, and finally they review and summarize their reading.

Two-column notes are made simply by folding notebook paper in half lengthwise, then labeling the left column "Main Ideas" and the right column "Details." As students read, they complete the notes by filling in the main ideas and corresponding details from the reading.

Venn diagrams, also known as *double bubble maps*, are overlapping circles used to compare different concepts, terms, or vocabulary words. Where the circles overlap, students list the similarities between the concepts, and where the circles are separate, students list the special properties or qualities of each concept separately.

Vocabulary maps are similar to free-form maps, but they have the vocabulary word in the middle. Lines are drawn to give examples of the word, and to describe what it is like.

APPENDIX B: INFORMED CONSENT LETTER

October 16, 2003

Dear Science Teacher:

I am a doctoral candidate at the University of Central Florida. My dissertation involves learning about how secondary science teaches address scientific literacy through content area reading and student inquiry. I am asking you to participate in this interview because you are interested in reading and science. The interview will last for approximately 60 minutes, and I have planned only a single interview with you.

With your permission, I would like to audiotape the interview. Only I will have access to the tape, which I will personally transcribe, removing any identifiers during transcription. The tape will then be erased. Your identity will be kept confidential and will not be revealed in the final manuscript.

There are no anticipated risks, compensation, or other direct benefits to you as a participant in this interview. You are free to withdraw your consent to participate and may discontinue your participation in the interview at any time without consequence.

If you have any questions about this research project, please contact me at coopers@hendry.k12.fl.us. My faculty supervisor is Dr. David N. Boote. Questions or concerns about research participants' rights may be directed to the UCFIRB office, University of Central Florida Office of Research, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL 32826. The phone number is (407) 823-2901.

Please sign and return this copy of the letter to me today. A second copy is provided for your records. By signing this letter, you give me permission to report your responses anonymously in my dissertation.

Sincerely,

Susan J. Cooper

I have read the procedure described above for being interviewed regarding reading in secondary science classrooms. I voluntarily agree to participate in the interview, and I have received a copy of this description.

________________________   _______________________/____________

Print Name   Signature   Date

APPENDIX C: IRB APPROVAL FORM

IRB COMMITTEE APPROVAL FORM
FOR UCF/OOR/IRB USE ONLY

PI(s) Name: Susan Cooper
Title: Addressing Scientific Literacy through Content Area Reading and Processes of Scientific Inquiry: What Teachers Report.

Check as applicable (optional):

[ ]Yes	[ ]No	Have sufficient assurances been given to the committee to establish that the potential value of this research exceeds the risks involved?
[ ]Yes	[ ]No	Written and oral presentations must be given to participating subjects (parents or guardians, if minors) informing them of the protocol, possible risks involved, the value of the research, and the right to withdraw at any time.
[ ]Yes	[ ]No	A signed written consent must be obtained for each human subject participant.
[ ]Yes	[ ]No	Are cooperating institutions involved? If yes, was there a sheet attached providing the name of the institutions, the number and status of participants, name of the involved official of the institution, telephone, and other pertinent information?

Committee Members:

Dr. Theodore Angelopoulos: ______
Ms. Sandra Browdy: ______
Dr. Jacqui Byers: ______
Dr. Ratna Chakrabarti: ______
Dr. Karen Dennis: ______
Dr. Barbara Fritzsche: ______
Dr. Robert Kennedy: ______
Dr. Gene Lee: ______
Ms. Gail McKinney: ______
Dr. Debra Reinhart: ______
Dr. Valerie Sims: ______

[ ] Contingent Approval
Dated: ______

[ ] Final Approval
Dated: ______

[X] Expedited
Dated: 30 Sept 2003

[ ] Exempt
Dated: ______

Chair, IRB
Signed: ______
Dr. Sophia Dziegielewski

APPENDIX D: FIRST LEVEL CODES

First Level Codes

Class routines

Encouragement/Motivation/Anticipation

Future Needs

Influences

Labs

Modeling

Problems

Reading assignments

Reading materials

Reading problems

Reading strategies

Science and reading

Scientific literacy

Staff development

Student behaviors

Student inquiry

Student involvement

Teacher changes

Textbook structure

APPENDIX E: MATRIX OF FINDINGS AND SOURCES FOR DATA TRIANGULATION

Matrix of Findings and Sources for Data Triangulation

Core Categories	Source of Data	
	Focus group	Individual
Causal Conditions: Influencers		
• Florida Science Standards	X	X
• FCAT Reading	X	X
• School-wide initiatives	X	X
• Professional development	X	
• Textbooks	X	X
Central Phenomenon		
• Instructional modifications	X	X
• Scientific Literacy	X	X
Context: Issues		
• Availability of reading materials	X	X
• Vertical articulation	X	
• Home support		X
• Lack of time	X	X
Intervening Conditions: Perceptions		
• Teacher beliefs	X	X
• Student reading problems	X	X
• Reading and science connections	X	X
Implementation Strategies: Class Routines		
• Labs	X	X
• Reading assignments	X	X
• Reading strategies	X	X
• Modeling reading strategies		X
• Student inquiry	X	X
• Motivation strategies	X	X
Consequences: Future Needs		
• Desired teacher changes	X	X
• Student involvement in reading	X	X
• Collaboration with other teachers	X	X

APPENDIX F: CODE MAPPING

Code Mapping

Research Questions		
1. How have more experienced secondary science teachers successfully addressed the scientific literacy of their students through integration of content reading strategies and student inquiry activities?	2. How do teachers use reading in science?	3. How can secondary science content reading strategies be improved to promote scientific thinking?
Initial Codes		
Teaching modifications Class routines Anticipation Labs Modeling Reading assignments Reading strategies Student inquiry	Influences Professional development Textbook structure School initiatives FCAT Reading Reading materials Home support Lack of time	Reading problems Teacher beliefs Student behaviors Future needs Student involvement Teacher requests Collaboration
Categories		
Central Phenomenon: Instructional Modifications Implementation Strategies: Class Routines	Causal Conditions: Influencers Context: Issues	Intervening Conditions: Perceptions Consequences: Future Needs

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