2006-07-12

# Reading and Writing in Science: How do the Reform Documents Attend to the Fundamental Sense of Science Literacy?

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# READING AND WRITING IN SCIENCE: HOW DO REFORM DOCUMENTS ATTEND TO THE FUNDAMENTAL SENSE OF SCIENCE LITERACY?

By

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A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Arts

Department of Teacher Education

Brigham Young University

June 2006

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

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As chair of the candidates graduate committee, I have read the thesis of Kimberly Frandsen in its final form and have found that (1) the work's format, citations, and bibliographic style are consistent and acceptable and fulfill university style requirements; (2) its illustrative materials, including figures, tables, and charts, are in place; and (3) the manuscript is satisfactory to the graduate committee, thus suggesting that the student is ready for the final oral examination.

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# ABSTRACT

READING AND WRITING IN SCIENCE: HOW DO REFORM DOCUMENTS ATTEND TO THE FUNDAMENTAL SENSE OF SCIENCE LITERACY?



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The purpose of this study was to examine and describe fundamental literacy messages found within three major science reform documents: *Science for all Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and the *National Science Education Standards* (NRC, 1996). A qualitative content analysis was performed in an effort to reveal any messages or statements supporting fundamental science literacy. Results from this study indicate that key science reform documents do in fact contain multiple messages supporting the fundamental sense of science literacy, however, the nature of these messages, the quantity, placement and presence of negative literacy statements may impact the way teachers view or support fundamental literacy skills within the classroom. Implications concerning the role of science educators and science teacher educators are also discussed.

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# CHAPTER 1

# INTRODUCTION

Since World War II, science literacy has emerged as the overarching goal of science education nationally and the focus of the current national science education reform movement. In contrast to the reform efforts of the 1960s and 1970s, where the primary focus was on educating *future scientists* (Yee & Kirst, 1994), the emphasis now is to educate *all students* (American Association for the Advancement of Science [AAAS], 1990). The aim is to develop a scientifically literate citizenry who can contribute to society in productive and responsible ways as well as to empower individuals to knowledgeably confront personal and societal problems (AAAS, 1990, 1993; National Research Council [NRC], 1996). Because science and technology are increasingly recognized as central to our more global society, "scientific literacy has become a necessity for everyone" (AAAS, 1990, p. xvi). Thus, National Science Education Standards have been adopted, which describe the science knowledge, skills, values, and attitudes that all American students should acquire by the end of their total school experience (NRC, 1996).

There exists some confusion or disagreement within the science education community, however, concerning what is meant by science literacy or what is required to be considered "scientifically literate." Traditionally, descriptions of science literacy focus primarily on what Norris and Phillips (2003) refer to as the *derived sense* of science literacy. This definition places emphasis upon science content knowledge and the ability to use this scientific knowledge to think, reason, and problem solve in an effort to understand the big ideas of science. Other researchers (Norris & Phillips, 2003; Yore, Bisanz, & Hand, 2003), though comparatively smaller in number, argue that definitions of science literacy that emphasize only content knowledge, reasoning, and problem solving skills ignore the literacy component of science literacy. They argue that this literacy component—the ability to speak, read, write, and communicate within the field of science—is at the core of the development of science literacy. Moreover, these abilities combine to act as an "essential constitutive practice of science, whose study is as vital to science education as sails are to ships, bricks are to houses or engines to cars" (Osborne, 2002, p. 215). Norris and Phillips (2003) describe this "literacy component of science literacy" (Yore, Bisanz, & Hand, 2003, p. 690) as the *fundamental sense* of science literacy and suggest that it includes the ability to acquire skills and dispositions deemed necessary to *communicate* within the field of science. These abilities or skills are not included in definitions that focus exclusively on the derived sense of science literacy.

Literacy scholars and researchers also contend that basic or fundamental literacy or communication practices such as speaking, reading, and writing are essential to the development of literacy within specific content areas, such as science (Draper & Seibert, 2004; Moje, 1996). They argue that literacy within any field of knowledge requires both an understanding of the facts, concepts, and generalizations accepted within that discipline as well as a facility with the language that describes that knowledge or enables individuals to communicate about discipline-specific ideas. For example, Gee (2001) suggests that the development of literacy includes or "integrate[s] ways of talking, listening, writing, reading, acting, interacting, believing, valuing, and feeling (and using various objects, symbols images, tools, and technologies)" (p. 719) within a specific social context, group of people, or "Discourse" (see Gee, 1996). From this perspective, then, achieving science literacy is more than having a general knowledge of science. It includes the acquisition of the ability to talk, listen, write, and read about science. In short, science literacy includes the skills and dispositions necessary to communicate within the field of science (Norris & Phillips, 2003).

Assuming this broader definition of science literacy, it becomes problematic that many teachers at both the elementary and the secondary level emphasize only the acquisition of science content knowledge during science instruction (Ratekin, Simpson, Alvermann & Dishner, 1985). Indeed, teachers seem to either ignore the fundamental sense of science literacy or assume that other educators have adequately prepared students to be able to negotiate science texts. Secondary science teachers, for example, may assume that fundamental literacy skills have been taught at the elementary level, lie within the domain of the English teacher, or are skills that science teachers feel untrained or under qualified to teach (Barton, Heidema, & Jordan, 2002; Burnett, 1966; DiGisi, Lyman & Willett, 1995; Yore, 1991). At the same time, elementary teachers often teach science as an independent subject, focusing upon content instruction as separate and distinct from literacy instruction (Alvermann & Moore, 1991; Stewart & O'Brien, 1989). Additionally, these researchers note that literacy instruction at the elementary level emphasizes primarily the negotiation of narrative texts.

Although teachers of science (particularly at the secondary level) may not perceive their role as both science and literacy educators, content-area literacy specialists argue that science teachers remain the best qualified to teach fundamental literacy skills as they relate to science (Vacca, 2002). They contend that instruction in content-area literacy requires not only knowledge of content, but of the practices associated with communication within a particular field of study (e.g., science). Content-area teachers, these scholars argue, have become specialized within a particular field of study or Discourse and, because of this expertise, have acquired reading, writing, and other communication skills that are required within that community of practice (Draper & Seibert, 2004; Vacca, 2002). On the other hand, secondary English teachers have been prepared to teach reading and compositional skill associated with English literature. These teachers are not likely to have acquired the skills necessary to teach literacy practices within multiple, different content areas. The conclusion, then, is that teachers of science must assume the responsibility of instructing students in practices and skills associated with both the fundamental and derived senses of science literacy.

Controversy exists, however, whether teachers of science at any grade level have the preparation or the support necessary to understand or to fulfill this responsibility as it relates to the fundamental sense of science literacy. Indeed, based on typical science classroom instruction that focuses strictly on the acquisition of content knowledge (with or without process), it might even be assumed that teachers are not aware of the charge to develop both fundamental and derived senses of science literacy. Do national efforts to reform science classroom practice focus only on developing content knowledge? Or, do the messages of reform support both aspects of science literacy, as some researchers suggest?

As part of current efforts to restructure science education with a focus on science literacy, a number of documents have been developed. *Science for All Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and the *National Science Education Standards* (NRC, 1996) were among the early texts developed to support and promote reform goals and focus primarily upon "what constitutes adult science literacy," recommending "what all students should know and be able to do in science, mathematics, and technology by the time they graduate from high school" (AAAS, 1993, p. xi). In essence, these documents are intended to act as a framework for instruction for teachers of science, guiding their practice as they strive to ensure that all American students "regardless of their social circumstances and career aspirations" (AAAS, 1990, p. xviii) reach a standard level of science literacy.

If these documents are designed to be influential in achieving science literacy, it is important to examine the messages that they contain about science literacy. Specifically whether or not messages present within the documents focus on more traditional definitions of science literacy, emphasizing the derived sense of science literacy and ignoring the fundamental sense of what it means to be science literate? On the other hand, do messages exist that focus on the fundamental sense of science literacy? If so, are these messages explicit or are they implicit? Moreover, do these messages describe ways in which teachers of science should attend to the fundamental aspect of science literacy, and are these messages explicit in encouraging support of students' ability to negotiate science-related texts?

*Statement of the Problem*

If the primary goal of science education is to ensure a scientifically literate population, it is necessary for students to develop a basic understanding of science in both the fundamental and derived sense. Students must know essential facts, concepts, and generalizations that constitute a basic understanding of the body of knowledge that is science. They must also develop the skills and attitudes of scientific inquiry. Along with this derived sense of science literacy, however, they must also acquire the skills and abilities necessary to successfully negotiate science texts and to communicate appropriately and effectively within the discourse of science.

Although much has been written concerning the necessity or desirability of developing scientifically literate students in the U.S., particularly in the derived sense (see Norris & Phillips, 2002), content-area literacy specialists and a small body of science educators continue to argue that it is also necessary to explicitly focus on the fundamental sense of science literacy (Yore, 1991). However, to date, no close examination of the foundational reform documents and the messages they contain about science literacy has been conducted to reveal if these messages speak to the fundamental sense of science literacy. Additionally, there is little to suggest that the documents contain messages or suggestions that outline specific instructional procedures and practices.

*Statement of the Purpose*

The purpose of this study is to examine three major reform documents: *Science for All Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and the *National Science Education Standards* (NRC, 1996) to identify and describe the science literacy messages found within. More specifically, I will look at how these reform documents address literacy practices associated with the fundamental sense of science literacy ( Norris & Phillips, 2002) such as speaking, reading, writing, and other means of communication.

*Research Questions*

Specific questions that will guide this research include:

1. What messages about the fundamental sense of science literacy are present in *Science for All Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and *National Science Education Standards* (NRC, 1996)?
2. What specific instructional practices or procedures are described in these documents that support or promote the development of science literacy in the fundamental sense?

# CHAPTER 1

## REVIEW OF LITERATURE

Science literacy has emerged as the watch cry for the current science education reform movement, with the overarching goal that all U.S. students will achieve science literacy by the time they finish their K-12 experience (AAAS, 1990). Although this objective has the potential to profoundly impact how teachers think about and implement science instruction in their classrooms, notions of what constitutes science literacy differ. Science educators, for example, typically view science literacy as “being knowledgeable, learned, and educated in science” (Norris & Phillips, 2003, p. 224). This perspective focuses particularly on knowing science content (NRC, 1996), what counts as science (DeBoer, 2000), and how to use knowledge of science in problem solving (AAAS, 1990; NRC, 1996). Literacy educators, on the other hand, think in terms of language literacy, or the ability to read and write (Yager, 2005). From this perspective, a scientifically literate individual is able to successfully negotiate science text—to read and write in science. Other scholars, however, argue that science literacy includes two interrelated features: a *fundamental sense* of science literacy (the ability to read and write in science) and a *derived sense* of science literacy (a knowledgeability about science) (see Norris & Phillips, 2003). The perception of these scholars is that “reading and writing do not stand only in a functional relationship with respect to science, as simply tools for the storage and transmission of science” (Norris & Phillips, 2003, p. 226). Rather, “reading and writing are inextricably linked to the very nature and fabric of science” (p. 226). In short, knowledge of science and the ability to read and write in science are “constituent” elements of science literacy (p. 226).

The problem is that definitions used to describe science literacy are likely to influence the way teachers think about science instruction and, therefore, how it is taught (see Brickhouse & Bodner, 1992). Thus, if the goal is perceived to be a focus on content knowledge and problem solving, teachers are more likely to emphasize only the acquisition of science facts, concepts, generalizations, theories, and laws through a process of inquiry. On the other hand, if science literacy is understood to include features that would fall under both the fundamental and derived senses of what it means to be scientifically literate, science instruction in classrooms would likely include an emphasis on understanding content as well as negotiation of science-related text.

For the purposes of this study, I have elected to consider science literacy from the perspective that the fundamental sense of literacy is central to science literacy. Indeed, my view is that there is an intrinsic connection between knowing science and reading and writing in science. Thus, this chapter will focus on three bodies of literature in order to better understand science education's focus on science literacy and the origins of this emphasis. These lines of research include (a) the history of science education reform literature (b) efforts to promote science literacy through reform documents, and (c) perspectives on the components or features of literacy in general and science literacy in particular.

## History of Science Education Reform in the United States

### *The First Reform: The Curriculum Reform Movement*

Many people generally believe that the launching of the *Sputnik I* satellite by the Soviet Union on October 4, 1957, triggered the first of two major reform movements in science education in the United States. This act, however, merely served as a catalyst for reform efforts. The events of World War II had already focused attention on science and science education, and what later came to be known as the "Curriculum Reform Movement" (DeBoer, 1991, p.10) was well underway when the Soviet satellite was launched. Duschl (1990) explains:

> As much as anything else, the scientific know-how and technological wizardry of the United States contributed to the winning of the war. It was because of the impressive technological successes of World War II that NSF was created in 1950. These successes (radar, sonar, nuclear energy, jet airplanes, artificial rubber, to name but a few) made quite evident the important role technology would play in establishing the political, economic, and social health and strength of the United States in the years ahead. The National Science Foundation was charged with guaranteeing that our nation's potential in science research and science education would be exemplary. (p. 16)

The recognition that science, mathematics, and technology were fundamental to maintaining U.S. economic, technological and military superiority (Shymansky 1992) triggered an unprecedented interest on the part of the federal government and private industry in setting curriculum standards in science. Indeed, school curriculum had traditionally been controlled by individual school systems in response to the perceived needs of their communities. However, the concern was that World War II had produced shortages in the number of scientists and mathematicians (DeBoer, 1991). This worry was further heightened by continued low enrollment of U.S. students in higher mathematics and science courses (DeBoer, 1991). Additionally, scientists at the university level argued that with the tremendous advancements within the fields of science and technology, elementary and secondary school curricula were no longer adequately preparing students in the skills and knowledge necessary for success in college science courses (Yee & Kirst, 1994). Thus, politicians, scientists, educators, and business and industrial leaders argued for changes in elementary and secondary science education that would help prepare students for potential science careers. The goal of pre-college science education, they contended, should be to help alleviate the personnel shortages in scientific, technological and industrial fields (DeBoer, 1991).

At the same time, international competition from the Soviet Union in technology began to surface. Reports indicated that the Soviets were investing heavily in science and technology and, real or imagined, their scientific and technological achievements were perceived as a threat to national security. Thus, concerns already present as to the United States' ability to maintain military and technological superiority were further increased with the launching of the Soviet satellite, *Sputnik I* in 1957 (Yee & Kirst, 1994). The Soviet Union became the first country to successfully launch a satellite that would orbit the earth. Paranoia erupted as people realized that "the fact that the Soviets had the rocket power to launch *Sputnik* meant that they now also had the capacity to deliver the [nuclear] bomb on an intercontinental ballistic missile" (Wolf, 1979, p. 57). The U.S. was lagging behind the Soviets in the space race and public education was blamed for not producing enough mathematicians and scientists to compete with the Soviet (Yee & Kirst, 1994). Thus, the launching of *Sputnik I* significantly increased the urgency to reform the science and mathematics curriculum, now deemed "too soft, too inefficient, too unselective," (Tyack, 1974) at all educational levels. A crisis was declared; science and mathematics education instantly became a national priority.

As a result, the federal government made the decision to spearhead efforts to reform science education. Over the next 15 years, billions of dollars of government and private funds were devoted to developing programs and science associations that would help in the design of new curricula (Prather, 1993). One of the programs instituted at this time was the National Science Foundation (NSF). The main purpose of this organization was to conduct basic research and create future scientists. However, with the increase in pressure to revitalize science education, this agency would be used to orchestrate the development of new science and math curricula that would increase the production of scientists and mathematicians (DeBoer, 1991).

The educational reforms of the 1950s and 1960s were initiated with the primary aim of incorporating modern scientific knowledge into the curriculum and improving the inquiry skills of future scientists (DeBoer, 1991). The curricula that were developed with this purpose in mind were created by scientists and university faculty with little or no involvement from K-12 classroom teachers. These scientists felt that teachers lacked the scientific knowledge and skills necessary to teach science with enough rigor, so the curricula were designed to be teacher proof (Prather, 1993). These curricula were scripted so that classroom teachers "could not mess them up" (Yager, 1992, p. 905) and contained elaborate materials, handouts, and experiments that were designed to engage students in learning science content and applying scientific methods (Bybee, 1993). Eventually, 20 high school, 13 elementary school, and 8 junior high school science curriculum-development projects were either completely or partially funded by the federal government (Klopfer & Champagne, 1990). Similar projects were designed for mathematics education during the same time period.

The curricula that were developed during the Curriculum Reform Movement have since been identified as the "alphabet soup curricula" because they were usually referred to by their acronyms (DeBoer, 1991). At the elementary level, examples included: Science, A Process Approach (S-APA), Elementary School Science (ESS), Science Curriculum Improvement Study (SCIS), and Conceptually Oriented Program in Elementary Science (COPES). At the secondary level, the Biological Sciences Curriculum Study (BSCS) introduced new textbooks and student laboratory guides for biology classes. In addition, the Chemical Bond Approach (CBA) was developed to introduce students to logical thinking in chemistry (DeBoer, 1991).

Directed and written by scientists, the curricula were designed to prepare students for college science courses and potential science careers—science for scientists. Yee and Kirst (1994) summarize the objectives of the reform projects as follows:

> The objectives were to update the content, increase the rigor of the courses, offer more courses, and introduce the students to the process of science as actually performed by scientists. This required the reformers to identify what constituted the essential content of each subject area, to develop lessons that used open-ended "discovery method" instructional strategies and extensive use of laboratory experiments and field studies, and to provide an experience for students that was sufficiently interesting and engaging so as to encourage them to pursue further courses in college. (p. 162)

Because the projects emphasized "pure" science, little or no attention was given to technological or everyday applications that students could identify with and enjoy (Yee & Kirst, 1994).

By 1975, all government funding for the science education projects and programs was withdrawn. The NSF had attempted to support both curriculum development and implementation, and Congress accused the agency of “mandating” a national curriculum—an issue of contention between Congress and the foundation from the earliest days of the reform movement (Duschl, 1990). It was clear that politicians believed that the reform movement was not achieving its aims.

By this time, it was also apparent that the intentions of the curriculum developers had not been adequately transmitted to teachers and students; the reform efforts were not working (Duschl, 1990). Although the science content was accurate and the support materials designed to be used in the classroom were considered by many to be excellent (Klopfer & Champagne, 1990), the curriculum reform efforts had failed to change the way science was taught in the schools. Indeed, despite the development and dissemination of elaborate curriculum materials, it quickly became evident that the reform movement was failing (Prather, 1993). Scholars have explained that multiple issues combined to thwart reform efforts. First, few teachers used the materials as designed, and students and teachers viewed the curriculum as “elitist” and too difficult (Bybee, 1993; DeBoer, 1991; Yager, 1992; Yee & Kirst, 1994). Second, classroom teachers were left out of the development of the curricula and felt little need to support or implement these programs (Prather, 1993). Finally, it became clear the curricula failed to meet student needs and interests within the classroom. The curricula were based upon a subject-specific emphasis and failed to look at the big picture of social needs (Prather, 1993). Indeed, urban problems from massive population migrations to the cities and social issues regarding overpopulation and pollution brought focus back to the necessity of curricula designed to meet social and personal goals (Bybee, 1993).

By the end of 1970's the first reform movement had met with some success in terms of preparing a body of scientists, but had neglected the majority of the population. "Many scientists, mathematicians, and engineers were produced: but the informed citizenry needed to maintain a science and technology-dependent civilization had not followed" (Prather, 1993, p. 55). Thus, as the Curriculum Reform Movement began to wind down, people increasingly began to discuss the importance of creating a scientifically literate society and how this might be accomplished. An understanding of basic science concepts and their connection to living in a world that was increasingly influenced by science and technology began to be the focus of science education.

*The Second Reform Movement: Science for All Americans*

For a second time since the conclusion of World War II a "crisis" in science education was declared. Beginning in the early 1980s, merely 25 years after the launching of *Sputnik I* sparked a major national effort to upgrade the quality of science curricula and instruction in the nation's schools, the message that was broadcast by scientists, educators, public figures, and writers was that science education "is facing a crisis of unprecedented proportions" (Klopfer & Champagne, 1990, p. 133). This time, however, society was no longer focusing on beating the Soviets to the moon. Instead, it was recognized that science had begun to impact "our society, our economy, and our lives" (Hurd, in Bybee, 1993, p. x). As a result, a fundamental understanding and knowledge of science was acknowledged as an essential element for *all* Americans.

"*Science literacy*" emerged as a watch cry for a new reform movement in science education.

The term "*science literacy*" was first proposed in the early 1950's by Conant in the book *General Education in Science* (Cohen & Watson, 1952). Yet, this term did not receive much recognition until Hurd published his article entitled "Science Literacy: Its Meaning for American Schools" (1958), introducing science literacy as a major theme for science education. Although both scholars promoted science literacy as a goal for the general public (as opposed to the emphasis on science for scientists that had been the theme of the Curriculum Reform Movement), neither publication included a clear definition of how either author conceived of science literacy.

Nevertheless, educators, inspired by Hurd's notion of science literacy, began to participate in discussions and symposiums devoted to developing and defining this concept. Despite education researchers inability at the time to develop a singular definition of science literacy, these discussions led to the National Science Teachers Association (NSTA) adoption of science literacy as one of its main goals: "The major goal of science education is to develop scientifically literate and personally concerned individuals with a high competence for rational thought and action" (NSTA, 1971, p. 47).

As science educators began to further explore achieving equal education for all through science literacy, the publication entitled a *Nation at Risk* (National Commission on Excellence in Education, 1983) placed further public pressure upon the inadequacies of science education. The commission questioned the ability of American students to compete with those of other countries within science and mathematics fields. This document indicated that failures within public schools were placing the nation at risk

(Bybee, 1993), citing statistics which indicated American students to be performing far below European and Eastern countries. This report also included excerpts from Hurd's article, "Science Literacy: Its Meaning for American Schools" (1958), in which the author stated, "The United States is raising a generation of Americans that is scientifically and technologically illiterate" (p.10). In response to this report, further emphasis was placed upon achieving science literacy for all.

## Reform Documents Developed to Promote Science Literacy

During 1989 the American Association for the Advancement of Science (AAAS) hosted symposiums, the aim of which was to define the purposes and goals of science education and develop reform documents and curricula to meet these goals (Bybee, 1993). This year saw the publication of *Science for All Americans: Project 2061* (AAAS, 1990). This document was designed as a framework for ensuring scientifically literate citizens by the year 2061 and outlines what would be necessary to accomplish this goal. In short, the book is "a set of recommendations on what understandings and ways of thinking are essential for citizens in a world shaped by science and technology" (AAAS, 1990). The publication of *Science for All Americans* is viewed as "one of the most comprehensive and innovative statements of scientific literacy in the history of science education" (Bybee, 2003, p. 64).

In response to *Science for All Americans*, reformers of science education sought for working definitions of science literacy. *Benchmarks for Science Literacy* (AAAS, 1993) was published as a companion report, the goal of which was to further define what content knowledge students should acquire in order to be considered scientifically literate. "While the purpose of project 2061 is to present a compelling vision of achievable learning goals, that of *Benchmarks* is to chart the territory that will have to be traveled to reach those goals” (AAAS, 2003, p. x).

The 1980’s also brought with it a push for accountability and standards. The National Science Teachers Association, The National Academy of Science, and the National Research Council (NRC) worked together to create the *National Science Education Standards* (NRC, 1996). This document serves as a framework for district and classroom curricula content and includes teaching practices and assessment standards for students. In this document, science content and concepts are broken up into seven main areas: Science as Inquiry, Physical Science, Life Science, Earth and Space Science, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science. Each of these standards is further broken down by grade levels and include chapters devoted to teaching and assessment standards.

*Science for All Americans: Project 2061* (AAAS.1990), *Benchmarks for Science Literacy* (AAAS, 1993), and the *National Science Standards* (NRC, 1996) act as key frameworks and curriculum guides for science literacy instruction. These documents have placed the achievement of science literacy at the forefront of science education. They are fundamental to reform efforts and are considered to be instrumental to acquiring science literacy within the science classroom.

## Science Literacy

### *Literacy: General Literacy, Content-area Literacy, Science Literacy*

The science reform documents described above place the development of science literacy at the forefront of science education. Yet what is meant by science literacy is viewed differently by those within and out of science education fields. Science educators have traditionally viewed science literacy as the development of science knowledge and content. In contrast, literacy educators view science literacy as the ability to communicate in and about science. There exists another group who are seeking to bridge the gap between the two by suggesting that science literacy is the inclusion of both science knowledge in the derived sense, and communication of science in the fundamental sense (Norris & Phillips, 2003). In this section I will describe perspectives on the components or features of literacy in general, literacy within a content area, and science literacy in both a fundamental and derived sense.

### *General Literacy*

For many years general literacy was typically thought of as the ability to read and write printed text. These traditional notions of literacy were likely to treat reading and writing quite narrowly. “Traditional approaches to language have tended to look at it as a closed system. Any piece of language is treated as representation (representing) of some information” (Gee, 2001, p. 715). The ability to read in these closed systems was thought of in “terms of psycholinguistic processing skills” (Gee, 2001, p. 714) independent of the context in which they were used. Writing also was thought of in these limited ways. Writing was viewed as the way in which information is conveyed or represented.

Although reading and writing have traditionally been considered to be at the core of literacy, general literacy in the broad sense includes dispositions or skills that make one civilized. Literacy, it is felt, frees some of “humanity from a primitive state, from an earlier stage of human development. If language is what makes us human, literacy, it seems, is what makes us civilized” (Gee, 1996, p. 26). It is thought that literacy is the means by which man is able to socialize and communicate thoughts and ideas. Indeed, "across history and across various cultures, literacy has seemed to many people to be what distinguishes one kind of person from another kind of person" (Gee, 1996, p. 26).

The interpretation of literacy as simply reading and writing is also problematic because this would imply that it is devoid of the potential influence of social, cultural and constructual factors (Gee, 1996). Thus, researchers have argued to broaden thinking of what it means to be literate by advancing the concept of multiple literacies (Eisner, 1991). Multiple literacies can include literacies associated with cultural, civic, computer, technological, school and content literacies (Brown, 1991). The concept of multiple literacies extends beyond the practices of reading and writing printed text to include the ability to "construe meaning in any of the forms used in the culture to create and convey meaning" (Eisner, 1991, p. 125). The ramifications of this thinking, then, suggests the skills of reading and writing no longer define literacy; rather, reading and writing act as tools to obtaining literate thinking (Langer, 1989).

*Content-area Literacy*

With new research concerning multiple literacies more and more emphasis has been placed upon the development of content-area literacy. Literacy specialists have argued that there exist literacy skills unique to each content area. These skills represent the knowledge one needs to communicate with others in and about specific subject areas.

Gee (2001) describes content-area literacy as the ability to "integrate ways of talking, listening, writing, reading, acting, interacting, believing, valuing, and feeling (and using various objects, symbols, images, tools, and technologies)" (p. 719) within a specific social context, group of people, or "Discourse" (see Gee, 1996). From this perspective, learners must develop competence in content area Discourses if they want to develop the cognitive skills necessary to question, understand and solve real-life, complex problems in that field. In addition, the development of these Discourses is “intimately linked to the distribution of social power and hierarchical structure in society” (Gee, 1990, p. 4). Mastery of such Discourses identifies the learner as a socially meaningful member within that Discourse (Gee, 1990).

Literacy researchers (Draper & Siebert, 2004) argue that this type of literacy requires an extensive understanding or knowledge of the content and the skills required to communicate within a discipline. The communication skills associated with achieving content area literacy are influenced by different contexts and cultures. This being the case, it is necessary to look at skills such as reading, writing, speaking, and text comprehension in association within a specific content.

*Reading*

Reading within a content area is essential for an individual’s development of competence within a “Discourse” because it is through reading that the learner expands their experiences by constructing meaning and knowledge of subject-specific concepts and issues. Content area reading involves the “explicit development of reading strategies that help students engage and learn with content specific texts” (Vacca, 2002, p.184). It is a constructive and interactive process that is based upon the context of the content, the culture, and experience of the reader (Alvermann, 1994; Gee, 2001; Vacca, 2002).

Historically, reading within a content area was viewed as a one-way linear relationship between the learner and the text. The reader would merely recognize words and information located within text (Yore, et al, 2003). Today, however, reading is considered to be a two-way process between the reader and the text. Hand and his colleagues, suggests reading to be an "interactive and constructive process for making meaning constrained by criteria for good inferences in a sociocultural context" (2003, p. 612). This suggests that the text helps to develop new thought and insight, while the reader in turn interprets, analyzes, and organizes information for meaning or ownership (Yore, Bisanz, & Hand, 2003).

The constructive nature of the reading process is influenced by the context of the content in that the skills one uses to make meaning of text are not the same for each content area. For example, the strategies and skills a student uses to read and analyze a science textbook should differ from the way a literary novel is read (Vacca, 2002). According to Artley (1994), there exists a number of reading skills that are common to readers no matter the content. However, there also exists reading skills that hold special relationships to understanding and achievement in different subject areas.

A reader's culture can also influence the reading process by the way that culture embraces and identifies reading. Alvermann and Phelps (1994) indicate that "the culture of the classroom can influence how different cognitive strategies for learning from text are perceived, implemented, and assessed" (p. 50). In today's U.S. society, school literacy or reading of school textbooks is given a higher standing than other types of literacy. This means that students who struggle with reading in school may, in fact, excel in other forms of reading outside of the classroom.

The experiences readers have encountered throughout their lifetime affects the meanings they draw from text. Through the process of reading, a reader interprets information from the text with background knowledge that they have previously gained through experience. Yore, Bisanze, and Hand (2003) describe this process as a bottom-up and top-down process. During the bottom-up process, the reader will construct understanding in short-term memory by reading the text and analyzing information from past experience. This short term meaning is then evaluated using background knowledge from long-term memory to make global meaning or metacognition in the top down process. Through these two processes, students are able to connect knowledge that they have previously gained through experience to new language, vocabulary and concepts.

*Writing*

The ability to write is a critical component of achieving content area literacy. Writing is a form of communication that allows one to participate within subject-specific Discourses and improves depth of understanding and clarity of thinking. Traditionally, writing in a content area has been viewed as a means of assessment of content knowledge (Yore, Bisanze, & Hand, 2003). The writer would transcribe information from text or other sources with little or no analysis; it was a means of knowledge-telling (Yore, Bisanz, & Hand, 2003). Today, however, writing in a content area has evolved into a constructive process, one in which the student writes to learn (Yates, 1987). Writing to learn within a content area requires the writer to think, negotiate, plan, react, and reflect. This requires writing to be a multidimensional process, one in which the writer develops and constructs deeper knowledge and understanding of concepts within the content area.

*Oral Communication*

For one to become a participant within a Discourse or field of study, it is necessary for that individual to be able to not only understand oral speech and instruction, but to effectively communicate, or to act and talk so others within that field will be able to understand and recognize as well (Gee, 2001). Oral communication allows for the exchanging of ideas. Through oral communication the learner is able to establish relationships between people and events and give shape and meaning to experiences (Yates, 1987).

*Text*

To communicate within a specific content area, it is also necessary for students to be able to read and understand the types of texts associated with specific Discourses. Texts within a specific content area can be interpreted as cultural tools that influence the development of a Discourse. Moje, Dillon, and O'Brien (2000) describe text as "more than sites of information or aesthetic expression; they are cultural tools for establishing belongingness, identity, personhood, and ways of knowing" (p. 166). This definition of text supports the broadened view that content area texts cannot be limited to printed material, but must include anything that people use to create, convey, and negotiate meaning (Draper & Seibert, 2004). With this broadened view, such things as speech, diagrams, maps, and models must be included and defined as text.

*Science Literacy*

The literacy skills associated with the development of content area literacy such as reading, writing, oral communication and text comprehension are considered by some scholars to be an essential aspect of the development of science literacy. These researchers argue that although science content knowledge is an important part of the development of science literacy, without the ability to communicate within the discourse of science it is like "sailing a ship without a sail, building a house without bricks or driving a car without the engine" (Osbourne, 2002, p. 215).

Although science literacy has emerged as the watch cry for the current science reform movement, the definition or what is meant by the term science literacy is not universally understood even within the science education community. Traditional definitions of science literacy are based upon knowledge of science content and the ability to perform science. These definitions either do not include or subsume literacy practices supported by general or content-area literacy research. Phillips and Norris (2003), however, suggest that one cannot achieve science literacy in the full sense unless both science knowledge and the ability to communicate within the science content are addressed.

*The Derived Sense of Science Literacy*

Many science educators view science literacy as the ability to know and perform science. Deboer (1991), for example, defines science literacy simply as an understanding of science and its applications. Bybee (1997) suggests science literacy to be an ongoing process in which a person develops skills and an understanding of science. “Science literacy is a continuous process” (p. 81) one in which an individual continuously develops a greater and more sophisticated understanding of science. Shamos (1995) further argues that science literacy is not only a process, but also an unachievable goal, for it would require the ability to understand all of science research.

Phillips and Norris (2003) place definitions of science literacy described above under what they consider to be the *derived sense* of science literacy (p.1). These definitions focus upon students’ ability to be “knowledgeable, learned, and educated” (Phillips & Norris, 2003, p.224) in the field of science. The derived sense of science literacy includes a substantive knowledge of the content matter or the ability to memorize science content and grasp science concepts. It also includes an understanding of the nature of science and its relationship to other fields. Dispositions and skills associated with this sense include, but are not limited to, the following:

- Knowledge of science content material, concepts and theories
- Understanding and application of the big ideas of science
- An understanding of the nature of science and the social relevance of science
- Relationships among science, technology, society and the environment
- Processes and skills associated with the scientific method and inquiry: observation, questioning, experimenting, and analysis.
- Skills associated with the development of data collection and technology: measuring skills, computer skills, lab instruments (Yore, Bisanz & Hand, 2003).

*The Fundamental Sense of Science Literacy*

Language is an essential component of the development of scientific literacy. “Language can be viewed as a means of doing science and construing scientific claims, used to communicate inquiries, procedures, and science understandings” (Yore, 2005, p. 72). It is through language that the nature of science and scientists are communicated. Phillips and Norris (2003) suggest that definitions of science literacy that focus upon acquiring skills and dispositions deemed necessary to *communicate* within the field of science can be categorized under the *fundamental sense* of science literacy (1).

Phillips and Norris (2003) argue that reading, writing, text comprehension, and oral communication within the discipline of science are key components of developing this aspect of science literacy. The ability to read science content includes the ability to read, interpret, and make connections associated with different science texts. Writing includes the ability to utilize vocabulary to communicate with others both in and out of the field of science about science (Phillips & Norris, 2003; Yore, Bisanz, & Hand, 2003). Reading and writing is "essential for documenting the detailed associations among evidence, warrants, and claims; making utterances permanent; allowing scientists time to reflect on their thoughts, mental images, and claims; and establishing proprietorship of intellectual properties" (Yore, 2005, p. 72).

Oral communication is also a necessary component of science literacy. The ability to debate, argue and discuss science concepts and principles is highly valued within the community of science. "Oral discourse is vital for sharing ideas and stimulating thinking" (Yore, 2005 p. 72). Other skills associated with the fundamental sense of science literacy include:

- The traditions of being a learned person
- The ability to read and understand multiple science texts such as: textbooks, graphs, lab reports, newspapers, maps, diagrams
- The abilities to speak about science to different audiences both inside and out of the scientific community
- The ability to write science documents such as lab reports, and research articles
- The communication and emotional dispositions of science (Yore, Bisanz, & Hand, 2003).

Although Phillips and Norris (2003) have classified science literacy into two separate components (the derived and the fundamental sense), they argue that these two senses are intrinsically linked. It is impossible to develop aspects of one sense without the other. For example, in order for students to develop literacy skills associated with the derived sense, they must utilize the practices of writing and recording data associated with the fundamental sense. As a result, Phillips and Norris (2003) argue that for one to achieve full science literacy both aspects of the fundamental and derived senses must be attained.

*Attending to Science Literacy*

Although the achievement of science literacy is considered to be the goal of science education, little or no instruction associated with the fundamental sense of science literacy is taking place within science classrooms. Researchers suggest “that teachers at the middle and secondary school level generally spend a negligible amount of instructional time showing students how to use content area reading strategies” (Alvermann & Phelps, 1994, p. 45). These same teachers may feel that they are either inadequately prepared to teach the skills associated with the fundamental sense of science literacy, that these literacy skills should fall under the role of the English teacher, or that these skills should have been be taught at the elementary level (Barton, Heidema, & Jordan, 2002; Burnett, 1966; DiGisi, Lyman & Willett, 1995; Yore, 1991).

These perceptions of who should be responsible to teach or support the fundamental literacy skills required for science literacy are problematic. English teachers are not equipped with the proper science background knowledge to attain to both the fundamental and derived senses of literacy. They have been prepared to teach reading and compositional skill associated with English literature and not the science content. It is also problematic to assume that students have acquired fundamental literacy skills at the elementary level. Elementary teachers have a tendency to teach science as an independent subject, focusing upon content instruction as separate and distinct from literacy instruction (Alvermann & Moore, 1991; Stewart & O'Brien, 1989). Additionally, literacy instruction at the elementary level emphasizes primarily the negotiation of narrative texts rather than the expository texts that are specific to the language of science.

Literacy researchers emphasize that it is necessary for content area educators to teach the skills associated with their content. This suggests that science educators are those individuals best prepared to instruct students in all aspects of science literacy. It is the science educator who has acquired the proper background knowledge of science content *and* the skills necessary to communicate within that field (Draper & Seibert, 2004; Vacca, 2002). Therefore, if full science literacy is to be reached, science educators must be the ones who teach both the skills and practices associated with the fundamental and derived senses of literacy.

*Science Reform Documents and the Fundamental Sense of Science Literacy*

The literature suggests that literacy educators, content-area literacy specialists, and science educators and researchers broadly support the need for science literacy to be taught in the science classroom. Yet, even with continued emphasis and national goals focused on every student achieving science literacy, many science educators continue to spend a negligible amount of time teaching the skills associated with the fundamental sense of science literacy to children in their classrooms (Alvermann & Phelps, 1994). Indeed, many children at all grade levels struggle to successfully negotiate science-related expository texts. Although multiple reasons have been posed as to why this may be so, including the notion that many science teachers may assume that teaching fundamental literacy skills is the responsibility of other educators, it may be that the messages of science educators and reformers largely ignore the fundamental sense of science literacy.

The focus of this study is to conduct an in-depth analysis of three major science education reform documents—*Science for All Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and *National Science Education Standards* (NRC, 1996)—and the messages that they contain concerning science literacy. These publications contain widely accepted definitions of science literacy that are assumed to have a profound impact on what happens in science classrooms nationally.

My goal is to investigate both the messages these documents contain and what instructional practices and procedures are described within them that support the development of the fundamental sense of science literacy.

# CHAPTER 3

# METHODS AND PROCEDURES

## *Design*

This study sought to answer questions regarding messages about the fundamental sense of science literacy (see Norris & Phillips, 2003) contained within three major science reform documents: *Science for All Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and the *National Science Education Standards* (NRC, 1996). More specifically, I looked at the ways in which these documents attended to the fundamental sense of science literacy. With this purpose in mind, the research methodology used to conduct this investigation was a qualitative content analysis.

Content analysis can involve both quantitative and qualitative strategies. Like all research techniques, its purpose is to provide "new insights, a representation of 'facts' and a practical guide to action" (Krippendorff, 1980, p. 21). Traditionally, content analysis is performed using quantitative designs in which the researcher selects categories a priori and analyzes the data based upon the frequency of terms within the text (Holsti, 1996; Krippendorff, 1980). Qualitative content analysis, on the other hand, differs from quantitative content analysis in that it is the process in which "documents are analyzed to communicate or reveal a person's or group's conscious and unconscious beliefs, attitudes, values, and ideas" (Fraenkel, & Wallen, 1993, p. 389). Qualitative content analysis uses "reflexive analysis" (Altheide, 1987) to reveal both implicit and explicit messages that may be hidden within documents or text. According to Altheide (1987), reflexive analysis is a type of analytic induction in which constant questioning leads to the development of categories or themes that emerge from within a text.

Because I examined documents representative of current science education goals and reform, it was necessary for me to conduct a qualitative content analysis of the data rather than a quantitative content analysis. A qualitative approach was appropriate for my study because I was not looking at the *number of times* science literacy in a fundamental sense (Norris & Phillips, 2003) might be found within the documents. Rather, the goal was to identify descriptions of the fundamental sense of science literacy and the instructional practices associated with achieving this type of science literacy. Additionally, the reflexive analysis associated with this type of qualitative analysis allowed me to determine the explicit and/or implicit nature of these descriptions.

*Documents*

The three documents chosen for this study were not randomly chosen, but were selected specifically because of their intended impact on restructuring science education and promoting science literacy in the United States. Together, these three documents act as a framework for the current reform movement in science education and include goals and standards for curriculum development, classroom instruction, and assessment (AAAS, 1990; AAAS, 1993; NRC, 1996). *Science for All Americans: Project 2061*, published by the AAAS in 1990, issued the goal for science education to ensure a scientifically literate citizenry by the year 2061. This document includes a "substantive view of scientific literacy, the knowledge, skills, and attitudes that all students should acquire" (Bybee, 1997, p. 64) by the end of the twelfth grade. *Benchmarks for Science Literacy* (AAAS, 1993) was chosen for this study because it is a companion report to *Science for All Americans: Project 2061* (1990). The purpose of this document is to clarify messages concerning science literacy, content knowledge, and the goals established in *Science for All Americans: Project 2061* (AAAS, 1990). Finally, *National Science Education Standards* (NRC, 1996) was also developed in consequence of the nationwide systemic reform in science education. This document seeks to improve science education and promote science literacy by including "standards for teaching, professional development, assessment, content, program, and system" (Bybee, 1997, p. 91).

*Data Analysis*

The science education reform documents selected for this study were read with the intent of discovering categories or themes regarding definitions and practices associated with achieving the fundamental sense of science literacy (see Norris & Phillips, 2003). I was not searching for and counting specific key words or sentences within the documents, but was looking for phrases or ideas that define or promote the fundamental sense of science literacy. This investigation was conducted in three distinct phases, which will be described in the following sections.

*Phase I*

I began the first phase of data analysis by identifying and separating the messages about science literacy found within each document into two a priori categories: (a) those that describe or refer to the fundamental sense of science literacy and (b) those that are representative of the derived sense of science literacy (see Norris & Phillips, 2003). In order to accomplish this, I looked specifically for literacy messages regarding practices involved in reading, writing, oral communication, and any other use of science text. These messages were categorized as those that described the fundamental sense of science literacy and were highlighted in the documents. All other science literacy messages in the texts were considered to be related to the derived sense of science literacy.

*Phase II*

During this second phase, “reflexive analysis” (Altheide, 1987) was used to uncover or unearth different themes or patterns within the initial grouping of fundamental literacy skills. Altheide (1987) describes reflexive analysis as the constant interaction that takes place between the researcher and the documents when allowing patterns or themes to emerge. This type of analysis greatly differs from the procedure used in phase one in that predetermined categories were not used. Instead, a process of inductive reasoning occurred, during which I was required to be “systematic and analytic, but not rigid” (Altheide, 1987, p. 68) in developing and defining further categories that emerged from the data. As I reread the messages from the texts that support or describe fundamental science literacy skills, I cut them out and began to sort them into categories according to the type of fundamental literacy skill they represented: reading, writing, or oral communication. Finally, each of these groups of messages was then separated into two subgroups: explicit messages and implicit messages. Additionally, questions regarding the categories also emerged during this phase of analysis which would later be used to guide further analysis during *Phase III*.

*Phase III*

During *Phase III* of the data analysis I examined the relationships between the categories that had emerged and the questions that were developed during *Phase II*. This allowed me to condense or redefine my categories for further reading of the documents.

The documents were then read multiple times with the defined categories acting as a guideline. Strauss and Corbin (1989) describe this process as theoretical sampling, a process in which categories become denser and tighter. I read the documents until I had reached "theoretical saturations" (Strauss & Corbin, 1989, p. 158) or had placed all data within a specified category and had ensured that any further reading would reveal no new themes or categories.

*The Researcher*

Experience and knowledge can play an active role in sensitizing the researcher during analysis of the data (Strauss & Corbin, 1998). This being the case, it is necessary for me to include a description of myself, as researcher. I am currently enrolled in a Teacher Education masters program which includes a course in content literacy instruction (Teacher Education 603). This course introduced me to current research concerning different definitions of text, reading, writing, and communication within different content areas or disciplines. This course also helped me to become more aware of differences in the way individuals view literacy. In particular, I am now aware of the contrasting perceptions of literacy from individuals within science education and those of literacy specialists. I also have a strong background in science education, having graduated with a bachelor's degree in Biology Composite Teaching. I have taught both physical and biological sciences at the secondary level within the public school system. Thus, it is through both of these lenses that I looked at the reform documents and determined the nature of the science literacy messages related to the fundamental sense of science literacy found within them.

*Reliability*

Because the methodology used for this study is qualitative in nature, I was the primary or central instrument in investigating, coding, and analyzing the data. As a result, the categories that developed during this type of research relied heavily upon my own interpretations and can be open to bias. To help minimize this bias, it was therefore necessary to ensure reliability by enlisting the help of three other readers who were asked to read and code pieces of the documents. All three readers were graduate students in a Teacher Education program and had participated in at least one content area literacy class. As a result, these teachers were familiar with the same definitions of literacy and text that I used to interpret the data.

Each of the three readers was given sections from two of the three texts so that up to 10% of each text was read and coded by two different readers in addition to myself. Each reader was also given a table of the categories that had been identified during *Phase I* of the data analysis and were asked to underline any literacy messages found within the texts. They were also asked to place the page number of the literacy message in the categories which they felt best applied. The readers were given one to two weeks to read and code the differing texts. Then, to measure reliability I checked the readers' underlined messages and the categories against my own and calculated a percentage of literacy messages that matched my own versus ones that were marked or were not placed in the same category as my own.

The first round of reading did not produce the required percentage of reliability with two of the three readers. It was, therefore, necessary for me to meet with the two readers whose results were below the required 90% compatibility and review how each viewed the categories. From this discussion it was revealed that what was meant by several of the categories were, too broad, unclear, or confusing to the reader. Consequently, together we further defined the categories to help make them clearer to each reader. The readers were then given another section of the document to read and code according to the more defined categories and another percentage was again calculated as described above. The second reading resulted in 90% compatibility with the two other readers.

*Limitations*

The documents used in this study are only a small sampling of the extant science reform materials. Because I am only analyzing three documents, there is a possibility that other texts take a different approach to the fundamental sense of science literacy. These materials may include descriptions of both fundamental and derived senses of science literacy and may even include subheadings or chapters devoted to achieving both senses of scientific literacy. However, *Science for All Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and the *National Science Education Standards* (NRC, 1996) are considered to be key documents that are intended to be instrumental in achieving reform in science education.

Another limitation to this study is the fact that I am assuming that teachers of science are familiar with or have read the documents used within this study. I am also assuming that teachers use these same sources as a guideline or reference for instruction within their classrooms. However, if teachers do not read these documents, they cannot be influenced by the messages related to literacy found within. It is reasonable to assume that there exists a possibility that many teachers of science may not be familiar with these documents in that it is not required reading by many school districts or even by many science education teacher preparation programs. Yet, with the increase in current state and national testing, science teachers are being held more and more accountable for meeting state and national standards associated with these documents.

# CHAPTER 4

# RESULTS

A qualitative content analysis was performed to identify and describe the literacy messages and teacher practices associated with the fundamental sense of science literacy contained in three major science reform documents: *Science for all Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (NRC, 1996). Through this process it was revealed that all three documents do contain messages that promote science instruction that attends to the fundamental sense of science literacy. These literacy messages are both explicit and implicit in nature and vary in emphasis and quantity depending upon the document. However, although these fundamental science literacy messages are present, they are relatively small in number when compared to those that support the derived sense of science literacy. This chapter will describe the nature of the messages found within the texts that support the fundamental sense of science literacy. Specifically, the chapter will be devoted to a description of the (a) quantity and placement of these messages, (b) categories or descriptors of messages that emerged during *Phase II* of data analysis, (c) questions that arose concerning the nature of these messages, and (d) any messages or statements found in the documents that may be interpreted as negative or contrary to developing the fundamental sense of science literacy.

## *Quantity and Placement of Messages*

Quantity, placement, and emphasis of ideas portrayed through text within a document can play a critical role in how documents are interpreted and understood by the reader (Buehl, 2003). Indeed, the intentional or unintentional placement of text in different areas of a document can suggest to the reader that one statement, idea, or chapter is more important than another. Buehl (2003) goes as far as to suggest that "the language in which text is written and the text's organizational structure, from the sentence level up through entire chapters or units, play a critical role in the process of constructing meaning" (p. 6). Additionally, the number of statements or the use of bold-faced type is likely to indicate to the reader what is most critical and what should first be read or understood. As I first read through the documents, I became particularly aware of the importance of attending to these patterns of emphasis or placement.

Although messages supporting both the derived and fundamental senses of science literacy were found to exist in all three documents, the space devoted to and the number of messages that pertain to the fundamental sense of science literacy is dwarfed as compared to the overwhelming quantity of messages devoted to the derived sense of science literacy. This is evidenced by the finding that all three documents include multiple chapters dedicated to the development of science content, student inquiry, teacher development, and assessment while not a single chapter in any of the three documents is completely allocated to developing skills associated with the fundamental sense of science literacy.

Of the fifteen chapters found in the document *Science for All Americans: Project 2061* (AAAS, 1990), twelve were almost exclusively devoted to the development of the derived sense of science literacy. The last three chapters articulated the future goals for reform. Not one chapter was exclusively devoted to the development of the fundamental sense of science literacy. The document *Benchmarks for Science Literacy* (AAAS, 1993) was similar to *Science for All Americans: Project 2061* (AAAS, 1990) in chapter sequence and organization. Of the sixteen chapters included in this document, twelve chapters were almost exclusively devoted to developing the derived sense of science literacy. The remaining four where dedicated to explaining the origin, background and the research base for the development of the document. The *National Science Education Standards* (NRC, 1996) differed from the other two documents in chapter organization and structure. This book is organized into eight chapters based upon a history of the development of national science education standards, science standards definitions and policies, science instruction standards, teacher development standards, assessment standards, science content standards, and program and system standards. As with the other documents examined, however, not one chapter in this book is exclusively devoted to the development of fundamental science literacy skills.

A pattern concerning the placement of existing fundamental science literacy messages within each document also emerged. Indeed, the majority of messages supporting the fundamental sense of science literacy are found within only one or two chapters in each of the three science reform documents. Moreover, the bulk of the fundamental sense of science literacy messages found in two of the three documents, Science *for All Americans: Project 2061* (AAAS, 1990) and *Benchmarks for Science literacy* (AAAS, 1993), were found in the very *last* chapter of each book, under the chapter title of “Habits for Mind.” Too, the majority of the messages related to the fundamental sense of science literacy found in the *National Science Education Standards* (NRC, 1996) are located in the fifth chapter (out of eight total chapters), entitled “Assessment in Science Education.”

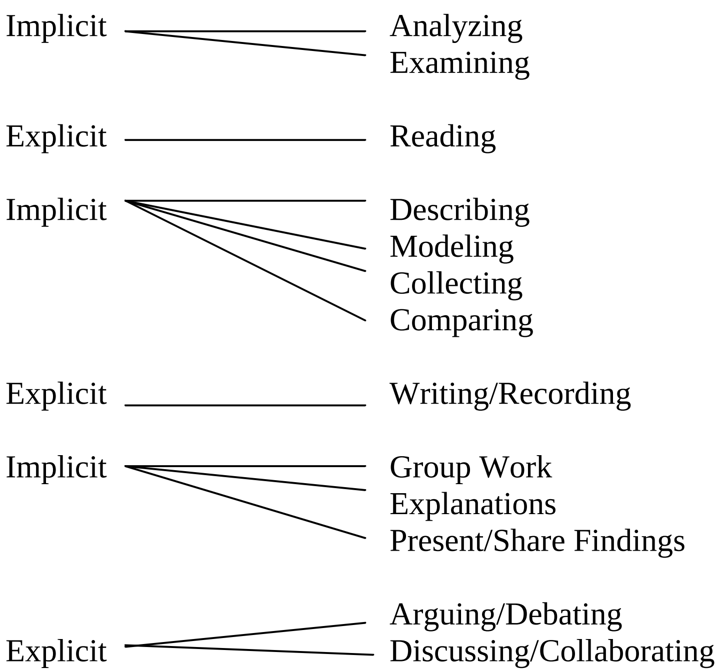
*Categories of the Messages*

Messages concerning the fundamental sense of science literacy identified during *Phase I* were initially grouped during *Phase II* into thirteen different categories based on the type of fundamental literacy skill described, defined, or mentioned: analyzing, examining, reading, describing, modeling, collecting, comparing, writing or recording, working in groups, proposing explanations, discussing or collaborating, arguing or debating, and presenting or sharing findings. After further examination of the messages placed into these thirteen initial categories, it was also clear that the quality or character of the way each message was given or presented should also be noted. Thus, the categories were separated based on the nature of the message itself as "implicit" or "explicit." Explicit literacy messages were those messages that specifically discuss or name the process of learning or performing skills or habits of reading, writing, or oral communication. Implicit messages were those that did not specifically discuss or name the process or skill of reading, writing, or communicating orally. Rather, these messages discuss or describe activities or actions that are likely to require these literacy skills in order to perform the task. This categorization is shown in Figure 1.

After the original categories were organized according to whether they were implicit or explicit messages, it then became apparent that these messages could be collapsed into three major categories: reading, writing, and oral communication. Thus, as illustrated in Figure 2, the three main categories are split into subgroupings based on the nature of the message (implicit or explicit) and then separated into more specific categories based on the literacy skill described. Figure 2 illustrates this process and the final organization of the messages found within the reform documents that support the fundamental sense of science literacy. Each of the three major categories identified during this analysis (reading, writing, and oral communication) will be described in detail in the following sections of this chapter.

Figure 1

*Explicit and Implicit Messages Supporting Fundamental Science Literacy*

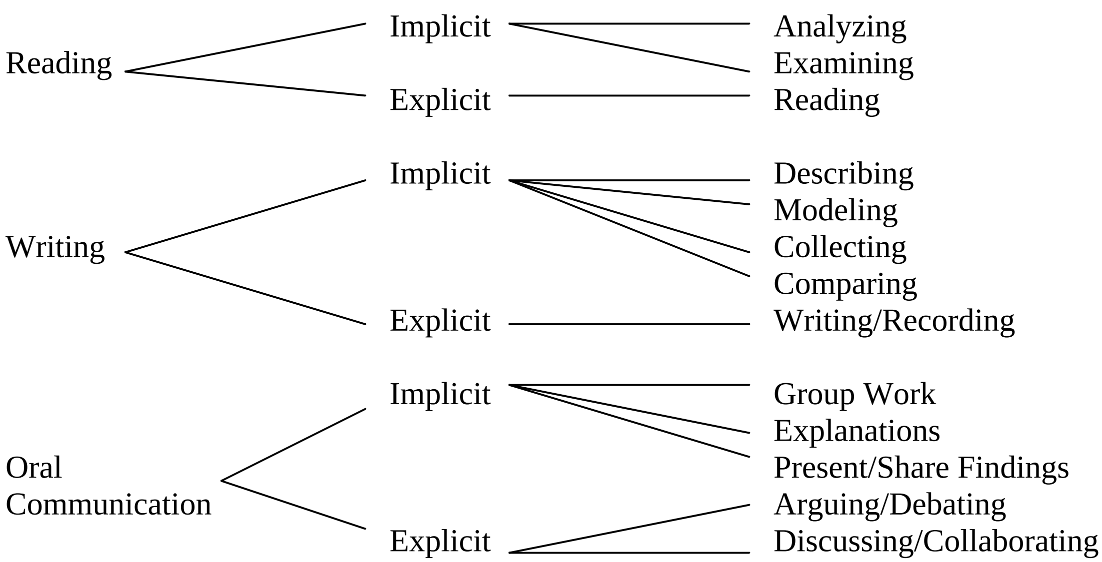



*Reading*

For the purposes of this study, it was necessary for me to define what is meant by reading and text. Reading is defined as the process of obtaining meaning or understanding from text (Buehl, 2003, p. 5). A reader is one who “constructs meaning from a text rather than merely reproducing the words on the page” (Buehl, 2003, p. 5). Text can be viewed broadly as anything that can create, or convey meaning (Draper & Seibert, 2004). For example text can include a multitude of things, including, but not limited to print, films, diagrams, teachers or experts. However, for the purposes of this study, the definition of text is somewhat more specific. Text here is considered to be any visual object, symbol, or print representative of meaning.

Figure 2

*Final Categories of Messages Supporting Fundamental Science Literacy*




Based on these definitions, messages or statements that were placed in the reading category were those that either explicitly or implicitly indicated the reading of texts (see Figure 1). Explicit reading messages were those that explicitly or specifically discussed the process of reading. Examples of explicit messages include the description of the ability of students to "*read* with understanding" (NRC, 1996, p. 31, italics added) or students' ability to "*read* articles in the popular press" (NRC, 1996, p. 22, italics added). The words *read* or *reading* had to be part of the statement for this message to fall under the "explicit reading" category. In contrast, messages that were considered to be implicit were those that did not specifically address the process of reading; however, reading was required to perform the task or tasks. These implicit messages included key words such as analyzing, or examining which would indicate that the process of reading was necessary to complete the activity. Examples of implicit messages are: “students will organize and interpret data” (NRC, 1996, p. 99), “students will analyze explanations” (NRC, 1996, p. 13), and students will conduct an “examination of evidence” (AAAS, 1990, p. 5).

All three documents include both explicit and implicit reading statements or messages. *Science for all Americans: Project 2061* (AAAS, 1993) explicitly and implicitly suggests that science discourse should include the ability to read or analyze with understanding “values from pie charts and simple bar and line graphs, false-color maps, and two way data tables” (p. 193); “instruction manuals” (p. 189); and “readings from standard meter displays, both analog and digital” (p. 192). The types of explicit and implicit messages regarding reading in science found within *Benchmarks for Science Literacy* (AAAS, 1993) include the ability to read, analyze, or examine “simple tables and graphs produced by others” (p. 197); “digital meters on instruments” (p. 294); “step by step instructions” (p. 290); “historical examples” (p. 4), “science journals”, congressional testimonies, “films” (p.4), “books, articles, and databases” (p. 299) “science discovery stories” (p. 12), “biographies” (p. 4), “textbooks” (p. 4), “newspapers, magazines, “ (p. 297) “models” (p. 267), “maps” (p. 297), and “spreadsheets” (p. 291). Reading messages described in the *National Science Standards* (NRC, 2003) include the ability to read, analyze, or examine “media, books, and journals in a library” (p. 33), “government documents, and computer databases” (p. 31), “video, films, computer simulations” (p. 31), “electronic communication” (p. 45), and “data” (p. 23).

*Writing*

Messages placed in the "writing" category were those that refer to any type of recording or inscription of information or material in a variety of formats, including such things as lists, descriptions, graphs, data tables, portfolios, or essays. As with the reading category, it was necessary to differentiate the writing category into two subcategories: explicit and implicit messages about writing (see Figure 1). Messages that were considered to be explicit were those that specifically described the process of writing using words such as *write*, *record*, *create*, or *make*. Examples include: "students will record data and make graphs" (NRC, 1996, p. 26) and "students will express in writing basic ideas" (AAAS, 1993, p. 192). On the other hand, messages that were considered to be implicit were literacy statements in which the format in which information was to be presented was not explicitly described, but the process of writing would likely or possibly be necessary to complete the task. Examples of these types of messages include: "students will describe objects" (NRC, 1996, p. 1), students will "organize information into simple tables" (AAAS, 1990 p. 193), students will "compare consumer products" (AAAS, 2003, p. 299), and students will construct "physical and mathematical models" (AAAS, 1990, p. 207).

As with the reading category, all three documents contain both explicit and implicit messages about writing. *Science for Americans: Project 2061* (1990), for example, suggests that science literacy includes the ability to explicitly or implicitly "write procedures" (p. 193), "organize information into simple tables" (p. 193), and summarize data into "graphs" (p. 201), "algorithms" (p. 189), "instructions" (p. 189) and "notebooks" (p.191). Literacy messages associated with writing found in *Benchmarks for*

*Science Literacy* (1993) include the ability to “keep written records in bound notebooks” (p. 286) “record data in logs, and journals” (p. 10), “produce tables and graphs” (p. 294), summarize data into “spreadsheets” (p. 294) and “write instructions that others can follow” (p. 297). This document also included the skills required to “interpret and compare” (p. 291) and to “keep a note book that describes observations” (p. 293). Finally, the *National Science Education Standards* (1996) included explicit and implicit messages suggesting the ability to write in the form of “written reports” (p. 144); to develop “spreadsheets” (p. 144); to design “computer graphics” (p. 144); to keep “research notebooks” (p. 98); to create “journals” (p. 134), data “charts and graphs” (p. 134), “models” (p. 135), and “written critiques” (p. 99).

*Oral Communication*

Oral communication involves the skills necessary to effectively communicate orally with others both in and out of the science community (Gee, 1996). This requires the skills associated with working and communicating effectively in groups and the ability to orally present information to others (Gee, 1996). As with reading and writing, messages that described activities pertaining to the major category of Oral Communication were also split into two subcategories: explicit and implicit messages (see Figure 1). Again, explicit messages were those in which it was clear, based on a key word or words used to describe the activity, that oral communication was absolutely required to complete the task. In contrast, implicit oral communication messages were messages in which the ability to orally communicate was not specifically described as required to perform the task or assignment; however, this ability is more than likely to occur during the completion of the task. Examples of messages that were placed within this category include: “student’s ability to interact with teachers and peers” (NRC, 1996, p. 20), student’s capability to work in “small student groups” (AAAS, 2003, p. 182), and student’s capacity to “explain data and criticize arguments” (AAAS, p. 300, 1993).

Again, all three documents contain both implicit and explicit oral communication messages. *Science for All Americans: Project 2061* (AAAS, 1990) suggests that skills associated with achieving science literacy include the ability to: communicate in the form of “group activity” (p. 202), “participate in group discussions” (p. 193), “exchange information” (p.4) or “knowledge”(p. 34), “make logical arguments” (p. 199), and develop “explanations” (p. 6). Oral communication messages presented in *Benchmarks for Science literacy* (AAAS, 1993) included the ability to: “participate in group discussions” (p. 297), “propose different explanations” (p. 285), and “arguments” (p. 231), “share findings” (p. 15), and “conduct interviews” (p. 46). And finally, oral communication messages found within the *National Science Education Standards* (NRC, 1996) include: participating in “oral reports” (p. 144) and “discussions” (p. 144), proposing “explanations” (p. 145) “arguments” (p. 143), and working together in “small groups” (p. 98),

*Emerging Questions*

Through the reflexive process of content analysis (Altheide, 1987) questions regarding the categories that emerged during *Phase II* surfaced. As messages concerning reading, writing, and oral communication were clearly identified, I began to wonder about the nature and intent of these messages. First, I wondered if the literacy messages described in the documents pertained to students or if they were merely described as part of the nature of science. Too, I wondered if the literacy messages presented were skills or habits that students were just expected to know and to perform or if the documents actually indicated that students should learn *how* to perform these skills. I also wondered if the documents explicitly or implicitly stated who, if anyone should teach students these skills and, if so, for what purpose. I also questioned whether these skills were to be used merely for assessment purposes or as part of what it means to be science literate. Finally, I was troubled at the number of "negative" science literacy messages I had encountered. Negative messages were any statements, descriptions, or other messages that seemed contrary to developing fundamental literacy skills or that seemed to downplay the importance of the fundamental sense of science literacy. An example of this type of negative message would include, teachers "eliminating reading as a *barrier* to student response" (NRC, 1996, p. 92, italics added). The following list includes all of the questions that were developed during *Phase II* of the data analysis:

- Do these literacy messages describe skills students are expected to know and do?
- Do these literacy messages describe skills or habits that scientists or those who are science literate do?
- Are these literacy messages presented in a way that suggest students will learn fundamental literacy habits or skills in their science class?
- Do these literacy messages describe skills that students perform for assessment purposes?
- Do the documents mention who will teach students these skills? Are any examples provided?
- Do the documents contain any negative messages about fundamental literacy?

The questions listed above helped to create new categories to guide further readings of the documents during *Phase III.* These new categories included: (a) Student knowledge, (b) Nature of science, (c) Learning science, (d) Assessment, and (e) Teacher instruction. The following three tables (Tables 1-3) describe the results of categories emerging from Phase II of the readings separated according to the different documents. The information in these tables represent a crossing of the original categories shown in Figure 2 and the new categories defined above that emerged as a response to the questions developed during *Phase II*: (a) Student knowledge, (b) Nature of science, (c) Learning science, (d) Assessment, and (e) Teacher instruction. Each of these four categories will be described in detail in the following sections.

Table 1

*Messages Supporting Fundamental Science Literacy Present In Science For All Americans: Project 2061(AAAS, 1990)*

| Science for All Americans | | | Student Knowledge | Nature Of Science | Learning Science | Assessment | Teacher Instruction |
|---|---|---|---|---|---|---|---|
| Reading | Implicit | Analyze | X | X | | | X |
| | | Examine | X | X | X | | |
| | Explicit | Read | X | X | | | |
| Writing | Implicit | Describe | X | X | | | |
| | | Model | X | X | | | |
| | | Collect | X | X | | | X |
| | | Compare | X | X | | | |
| | Explicit | Write/record | X | X | | | |
| Oral Communication | Implicit | Group work | X | X | X | | |
| | | Explanations | X | X | | | |
| | | Present/ Share findings | X | X | | | |
| | Explicit | Argument/ debate | X | X | X | | X |
| | | Discuss/ collaborate | X | X | | | |

Table 2

*Messages Supporting Fundamental Literacy Present In Benchmarks for Science Literacy (AAAS, 1993)*

| Benchmarks for Science Literacy | | | Student Knowledge | Nature Of Science | Learning Science | Assessment | Teacher Instruction |
|---|---|---|---|---|---|---|---|
| Reading | Implicit | Analyze | X | X | X | | |
| | | Examine | X | X | | | |
| | Explicit | Read | X | X | X | | X |
| Writing | Implicit | Describe | X | X | X | | |
| | | Model | X | X | | | X |
| | | Collect | X | X | X | | X |
| | | Compare | X | X | | | |
| | Explicit | Write/record | X | X | X | | |
| Oral Communication | Implicit | Group work | X | X | | | |
| | | Explanations | X | X | X | | X |
| | | Present/Share findings | X | X | X | | X |
| | Explicit | Argument/ debate | X | X | | | |
| | | Discuss/ collaborate | X | X | X | | |

Table 3

*Messages Supporting Fundamental Science Literacy Present in The National Science Education Standards (NRC, 1996)*

| The National Science Standards | | | Student Knowledge | Nature of Science | Learning Science | Assessment | Teacher Instruction |
|---|---|---|---|---|---|---|---|
| Reading | Implicit | Analyze | X | X | X | X | X |
| | | Examine | X | | | | |
| | Explicit | Read | X | X | X | | |
| Writing | Implicit | Describe | X | X | X | | |
| | | Model | X | X | X | X | X |
| | | Collect | X | X | | | |
| | | Compare | X | | | | |
| | Explicit | Write/record | X | X | X | X | X |
| Oral Communication | Implicit | Group work | X | X | | | X |
| | | Explanations | X | X | | X | X |
| | | Present/ Share finding | X | X | X | X | X |
| | Explicit | Argument/ debate | X | X | X | X | X |
| | | Discuss/ Collaborate | X | X | | | X |

*Student Knowledge*

This category includes statements describing what students will know or be able to do. As well, these statements were limited to skills associated with students; statements that were placed in this category were required to be devoid of any explicit teacher instruction. These statements were also separated from those which indicated that students were learning how to perform or know the skill. Examples of this type of statement would include, “students will read with understanding” (NRC, 2003, p. 22) or “students should write about technology” (AAAS, 1993, p. 45). These statements only pertain to students learning how to perform the function. Table 4 indicates the fundamental science literacy skills students should know or be able to do according to each document.

Table 4

*Messages Supporting Fundamental Science Literacy That Students Know or Do*

| **Documents** | **Reading** | | | **Writing** | | | | | **Oral Communication** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Implicit** | | **Explicit** | **Implicit** | | | | **Explicit** | **Implicit** | | **Explicit** | | |
| | **Analyzing** | **Examining** | **Reading** | **Describing** | **Modeling** | **Collecting** | **Comparing** | **Writing/ Recording** | **Group work** | **Explanation** | **Present/ Share** | **Arguing/ Debate** | **Discuss/ Collaborate** |
| **A** | **X** | | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **B** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **C** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

*Note*: A= *Science for All Americans: Project 2061* (AAAS, 1990), B= *Benchmarks for Science Literacy* (AAAS, 1993), and C=*National Science Education Standards* (NRC, 1996)

It is apparent from the information displayed in Table 4 that all three documents contain explicit and implicit messages suggesting that students should know or be able to read, write, and orally communicate in science. *Science for All Americans: Project 2061* (AAAS, 1990) indicates that students should know or be able to "organize information into simple graphs" (p. 193), "collect" (p. 201), and "analyze" (p. 201), data, participate in "arguments" (p. 201) "read" multiple texts (p. 192), and "write" (p. 193) within the science context. *Benchmarks for Science literacy* (AAAS, 1993) indicates that students should know or be able to "notice and criticize arguments" (p. 300), read and analyze "graphs" (p. 300), "store and retrieve information" (p. 294), "produce tables and graphs" (p. 294), and "describe" (p. 293) and "compare data" (p. 291). The *National Science Education Standards* (NRC, 1996) suggests that students should be able to "organize" (p. 144) and "summarize data" (p. 145), "produce oral and written reports" (p. 144), participate in group "discussions" (p. 144), develop "spreadsheets" (p. 144), and read texts such as "media, books, and journals in a library" (p. 33).

*Nature of science*

The nature of science category included messages about literacy skills and habits that are performed by scientists or those considered to make one science literate. Examples of this type of statement would include: "scientists present their findings and theories in papers" (AAAS, 1990, p. 9) and "scientists strive to make sense of observations of phenomena by constructing explanations" (AAAS, 1990, p. 6). These statements do not explicitly indicate whether or not *students* should be able to perform the same skills, but make the assumption that if scientists perform these skills, science students should perform them as well. Also included in this category were explicit statements concerning those who are considered to be science literate, such as: A scientifically literate individual is one who can "engage intelligently in public discourse and debate about important issues that involve science and technology" (NRC, 1996, p. 1). The prevalence of these types of messages is shown in Table 5.

All three documents explicitly and implicitly suggest that reading, writing, and oral communication are abilities or skills related to the *Nature of Science*. The *National Science Education Standar*ds (NRC, 1996) indicates that either scientists perform or those who are science literate perform the following fundamental literacy activities that require reading, writing, or oral communication: "exchang[ing] of techniques, information and concepts" (p. 4), "constructing explanations" (p. 6), "data gathering" (p. 8), and "communicating" (p. 8) and presenting "their findings and theories in papers that are delivered at meetings or published scientific journals" (p. 9). *Benchmarks for Science Literacy* (AAAS, 1993) suggests that scientists or those who are science literate "facilitate the sharing of new information" (p. 295), write and publish in "refereed journals" (p. 295), "explain" (p. 288), "express their arguments quantitatively" (p. 289), "report and record" (p. 284), and "graph," (p. 271). *The National Science Education Standards* (NRC, 1996) suggest that scientists or those who are science literate also participate in using "models" (p. 117), "sharing and debating of ideas" (p. 32), "examin[ing] books and other sources of information" (p. 23) and gathering, analyzing, and interpreting data" (p. 23). The prevalence of theses messages are shown in table 5.

Table 5

*Nature of Science Messages that Support Fundamental Science Literacy*

| | **Reading** | | | **Writing** | | | | | **Oral Communication** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Implicit** | | **Explicit** | **Implicit** | | | | **Explicit** | **Implicit** | | **Explicit** | | |
| **Documents** | **Analyzing** | **Examining** | **Reading** | **Describing** | **Modeling** | **Collecting** | **Comparing** | **Writing/ Recording** | **Group work** | **Explanation** | **Present/ Share** | **Arguing/ debate** | **Discuss/ Collaborate** |
| **A** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **B** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| **C** | **X** | | **X** | **X** | **X** | **X** | | **X** | **X** | **X** | **X** | **X** | **X** |

*Note*: A= *Science for All Americans: Project 2061* (AAAS, 1990), B= *Benchmarks for Science Literacy* (AAAS, 1993), and C=*National Science Education Standards* (NRC, 1996)

*Student Learning*

This category describes messages that suggest that students are actually learning fundamental science literacy skills. For statements to be placed within this category, they must make reference to students actually learning a fundamental science literacy process or skill. Examples of statements that would be placed within this category could include: “students should learn what constitutes evidence and judge the merits or strength of the data and information” (NRC p. 122) and “students should begin developing the abilities to communicate” (NRC, 1996, p. 122). Statements that fall under this category must explicitly state the ability to learn how to perform the habit or skill, such “as students learn to write” (AAAS, 1993, p. 285) or it is “important for students to learn how to access scientific information” (NRC, 1996, p. 45). The prevalence of these types of messages is shown in Table 6.

Table 6

*Messages Supporting Students Learning Fundamental Science Literacy Skills*

| | **Reading** | | | **Writing** | | | | | **Oral Communication** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Implicit** | | **Explicit** | **Implicit** | | | | **Explicit** | **Implicit** | | **Explicit** | | |
| **Documents** | **Analyzin g** | **Examinin g** | **Reading** | **Describin** | **Modeling** | **Collectin g** | **Compari ng** | **Writing/ Recordin** | **Group** | **Explanati on** | **Present/ Share** | **Arguing/ debate** | **Discuss/ Collabor** |
| **A** | **X** | | | | | | | | **X** | | | **X** | |
| **B** | **X** | **X** | **X** | **X** | | **X** | | **X** | | **X** | **X** | | **X** |
| **C** | **X** | | **X** | **X** | **X** | | | **X** | | | **X** | **X** | |

*Note*: A= *Science for All Americans: Project 2061* (AAAS, 1990), B= *Benchmarks for Science Literacy* (AAAS, 1993), and C=*National Science Education Standards* (NRC, 1996)

It is clear from the information in Table 3 that the messages explicitly suggesting that students should learn how to perform fundamental literacy skills differ dramatically from document to document. *Science for All Americans: Project 2061* (AAAS, 1990), for example, contains a limited number of messages indicating that students should learn skills associated with reading and communicating in science. Messages supporting the notion of students learning fundamental literacy skills found within this document included such things as students learning how to "analyze information, communicate scientific ideas, make logical arguments" (p. 194) and "work as part of a team" (p. 194). *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (NRC, 1996) attend to the fundamental sense of science literacy more explicitly by suggesting that students should learn how to "write" (AAAS, 1993, p. 285), "describe their procedures" ( AAAS, 1993 p.16), "work in small teams" (AAAS, 1993, p. 15), develop "the abilities to communicate, critique, and analyze their work" (NRC, 1996, p. 122), "access scientific information" (NRC, 1996, p. 45), and learn the "oral and written discourse" of science (p. 36).

*Assessment*

The assessment category includes descriptions of fundamental literacy skills or practices used as a tool or tools to assess student knowledge or understanding of science content. An example of this type of message found in the *National Science Education Standards* (NRC, 1996) is a message that describes teachers using "portfolios; investigative projects; written reports; and multiple choice, short-answer and essay examinations" to assess (p. 84). To be included in this category, statements must include explicit reference to teachers using students' literacy skills for content assessment purposes or to measure student knowledge. Another example, taken from the *National Science Education Standards* (NRC, 1996), refers to teachers assessing students through "formal performance tasks, investigative reports, written reports, pictorial work, models, inventions, and other creative expressions of understanding" (NRC, 1996, p. 38). The prevalence of these messages in the documents is displayed in Table 7. Interestingly, of the three documents examined in this study, only one included messages suggesting fundamental literacy skills be used as a tool for assessment purposes: *National Science Education Standards* (NRC, 1996). It suggests that assessments of student knowledge or understanding should include "performances, portfolios, interviews, investigative reports, or written essays" (NRC, 1996, p. 6).

Table 7

*Messages Suggesting Fundamental Literacy Skills used in Assessment*

| | Reading | | | Writing | | | | | Oral Communication | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Documents** | **Implicit** | | **Explicit** | **Implicit** | | | | **Explicit** | **Implicit** | | **Explicit** | | |
| | **Analyzing** | **Examining** | **Reading** | **Describing** | **Modeling** | **Collecting** | **Comparing** | **Writing/ Recording** | **Group work** | **Explanation** | **Present/ Share** | **Arguing/ Debate** | **Discuss/ Collaborate** |
| **A** | | | | | | | | | | | | | |
| **B** | | | | | | | | | | | | | |
| **C** | **X** | | | | **X** | | | **X** | | **X** | **X** | **X** | |

*Note*: A= *Science for All Americans: Project 2061* (AAAS, 1990), B= *Benchmarks for Science Literacy* (AAAS, 1993), and C=*National Science Education Standards* (NRC, 1996)

*Teacher Instruction*

Teacher instruction includes those statements in which teachers of science would teach or provide instruction for fundamental science literacy skills such as reading, writing, and oral communication. Messages that would fall under this category would include such things as: “teachers will encourage informal discussion and structure science activities so that students are required to explain and justify their understanding” (NRC, 1996, p. 50), teachers “guide students in acquiring and interpreting information” (NRC, 1996, p. 31), or teachers teach the necessary skills as appropriate—and they promote many different forms of communication” (NRC, 1996, p. 36). What was not included in this category were statements such as: teachers will provide “opportunities for collecting, sorting and cataloging: observing, note taking and sketching" (AAA, 1990, p. 201). Although this kind of statement indicates that students would be performing a certain fundamental literacy skill or skills, what is unclear is whether teachers would also provide instruction to support students' ability to perform the skill. The appearance of these messages within the documents is described in Table 8.

Table 8

*Messages Supporting Teacher Instruction of Fundamental Science Literacy Skills*

| | **Reading** | | | **Writing** | | | | | **Oral Communication** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Implicit** | | **Explicit** | **Implicit** | | | | **Explicit** | **Implicit** | | **Explicit** | | |
| **Documents** | **Analyzing** | **Examining** | **Reading** | **Describing** | **Modeling** | **Collecting** | **Comparing** | **Writing/ Recording** | **Group work** | **Explanation** | **Present/ Share** | **Arguing/ debate** | **Discuss/ Collaborate** |
| **A** | **X** | | | | | **X** | | | | | | **X** | |
| **B** | | | **X** | | **X** | **X** | | | | **X** | **X** | | |
| **C** | **X** | | | | **X** | | | **X** | **X** | **X** | **X** | **X** | **X** |

*Note*: A= *Science for All Americans: Project 2061* (AAAS, 1990), B= *Benchmarks for Science Literacy* (AAAS, 1993), and C=*National Science Education Standards* (NRC, 1996)

It is notable that all three documents contained explicit or implicit statements indicating that science teachers play a role in the instruction of fundamental literacy skills. *Science for All Americans: Project 2061* (AAAS, 2000) indicates that students need "guidance, encouragement, and practice in collecting, sorting, and analyzing evidence, and in building arguments based on it" (p. 201). *Benchmarks for Science Literacy* (AAAS, 2003) suggests that teachers should instruct or place emphasis upon "mathematical modeling" (p. 270), "consistent use of language" (p. 251), communication of "findings" (p. 16), and "collecting and organizing information" (p. 15). The *National Science Education Standards* suggest that teachers should instruct or guide students in "data they will collect" (p. 144), "presentation of evidence, reasoned argument and explanations" (p. 50) and the "skills needed to work together" in groups (p. 50).

*Negative Literacy Messages*

The reform documents examined in this study also include a number of negative statements concerning the fundamental sense of science literacy. These messages either explicitly or implicitly contradict, discount, or reject the development of fundamental literacy skills. *Science for All Americans: Project 2061* (AAAS, 1990), for example, includes the following statement: "For teachers to concentrate on vocabulary, however, is to detract from science as a process, to put learning for understanding in jeopardy, and to risk being misled about what students have learned" (p. 203). Negative messages found in the *National Science Education Standards* (NRC, 1996) include those that suggest that teachers should place "*less emphasis on…textbooks*" or that "*maintaining current resource allocations for books*" is appropriate (NRC, 1996, p. 224, emphasis in original). Other messages suggest that teachers "eliminate reading as a *barrier* to student response" (NRC, 1996, p. 92, emphasis added); place "*less emphasis on… presenting scientific knowledge through lecture, text, and demonstration*" (NRC, 1996, p. 52, emphasis in original); and that good teachers are those that "ignore the vocabulary dense textbooks" (NRC, 1996, p. 12).

*Summary of Results*

It is clear that the three key science reform documents examined in this study do contain specific messages supporting fundamental science literacy. These messages appear to be both explicit and implicit in nature. Moreover, they are skills that (a) are associated with the nature of science, (b) students should know and be able to do, (c) students should learn within the science classroom, (d) are used for assessment purposes, and (e) science educators should encourage, support, and or teach. Although these messages are found in the documents, the nature of these messages, their quantity and placement, and the presence of negative fundamental literacy statements may cause science teacher educators or science teachers to miss or ignore the importance of the fundamental sense of science literacy or their role in supporting students' development of skills that would help to make them science literate.

# CHAPTER 5

## CONCLUSIONS AND RECOMENDATIONS

Although the key science reform documents examined in this study contain both explicit and implicit messages that support the fundamental sense of science literacy, there is a sense that this essential component of science literacy is awarded relatively little overall significance. There is even an impression that this sense of science literacy is taken for granted or assumed. Indeed, the small number of messages that relate to reading, writing or communicating in science, as well as the placement of these messages within each of the texts and finally, the negative statements found within the documents that are either intentionally or unintentionally contrary to the fundamental sense of science literacy may affect how science educators support science literacy and work to develop science literate individuals within their classrooms. This chapter will focus on a discussion of the messages related to the fundamental sense of science literacy that are stated or implied, the import that these messages are likely to hold, and the implications these messages may have for science educators and science teacher educators and how they view their roles as teachers of science.

### *Nature of Messages Supporting Fundamental Science Literacy*

*Science for All Americans: Project 2061* (AAAS, 1990), *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (NRC, 1996) were written in hopes of clarifying what it means to be science literate. Norris and Phillips (2003) argue that to achieve full science literacy one must address both the *derived* and *fundamental* senses of science literacy. Although all three documents include messages supporting both of these senses, the nature of the messages or the way in which fundamental science literacy messages are presented in these documents may cause the reader to miss or misinterpret fundamental science literacy messages.

As discussed in Chapter 4, fundamental literacy messages where categorized into five main categories: (a) fundamental science literacy skills associated with the nature of science, (b) fundamental science literacy skills that students should know or be able to do, (c) fundamental science literacy skills that students should learn in their science classes, (d) fundamental science literacy skills used for assessment purposes, and (e) fundamental science literacy skills that science educators should teach. It is important to note that all three documents strongly support only two of the five main categories. The documents clearly describe fundamental literacy skills as part of the nature of science or skills that scientists or those who are science literate know or perform. The documents also clearly suggest that students should know or be able to perform fundamental science literacy skills. The documents contain few messages, however, indicating where students are to learn these fundamental literacy skills. Moreover, these documents contain even fewer messages suggesting whose role it is to teach students such skills.

Prominent science reform documents are clear in suggesting fundamental literacy skills as part of what students must know and be able to do by the end of their K-12 experience. The lack of messages, however, supporting students learning fundamental science literacy skills within the science classroom, and more importantly the lack of messages indicating or describing the teachers role in supporting these skills may cause science teachers to ignore the development of fundamental science literacy within their classrooms. This supports research indicating that "content area teachers genuinely value the role that reading plays in learning, but fail to attend to reading in their own practices"

Vacca, 2002, p. 187). For years many science educators have either failed to adequately attend to or simply ignored the skills required for students to be able to read, write and communicate in science. These same teachers often consider skills associated with the *fundamental* sense of science literacy (reading, writing and oral communication) to be either taught at the elementary level or as skills associated within the domain of the English teacher (Alvermann & Moore, 1991; Stewart & O'Brien, 1989). However, this reasoning is likely to be problematic because English teachers are prepared to teach narrative reading and writing (literature) and are not likely to have developed the skills necessary to provide expository reading or writing instruction in science (Draper & Siebert, 2004). Elementary teachers, as well, tend to teach literacy skills separate from the content area instruction (Stewart & O'Brien, 1989).

If the science education reform documents were written to help create a science literate society then science educators must reconsider how they support the development of both the fundamental and derived senses of science literacy. Science educators, not English teachers, are the ones who are most familiar with science content and, more importantly, the types of reading and writing that are associated with understanding and performing science (Draper & Siebert, 2004). Science teachers must recognize that if students are to learn fundamental science literacy skills that will enable them to successfully negotiate science text in their everyday lives—to truly become science literate—teachers of science must take an active role in explicitly supporting the development of these skills. At the same time, science teacher educators must better support prospective and practicing teachers understand the importance of teaching these skills in the science classroom and the methods teachers can implement in order to do so.

*Placement and Negative Statements*

The explicit or implicit nature of what is communicated about the fundamental sense of science literacy through text as well as the quantity and placement of messages supporting this sense of science literacy may also have an impact on the interpretation or understanding of what it means to be science literate. The placement of the majority of messages supporting fundamental science literacy in the back of the documents could indicate to the reader (e.g., science teacher, science teacher educator, administrator) that these messages are much less important than messages supporting the derived sense of science literacy which are found in the beginning and middle of the document. Secondly, that the vast majority of messages in the documents support the derived sense of science literacy as opposed to the fundamental sense may also cause the reader to sense that the derived sense of science literacy is more important or that more time and emphasis should be spent developing this sense over the other. Finally, the large number of implicit verses explicit fundamental literacy messages may also cause the reader to miss or overlook messages supporting fundamental science literacy.

The existence of negative science literacy statements may also cause teachers to miss or ignore the development of fundamental science literacy. With the vast majority of the document already devoted to developing derived literacy skills the existence of these messages may cause science educators especially beginning teachers to question their need to support the fundamental sense of science literacy. Statements suggesting reading to be a "*barrier*" (NRC, 1996, p. 92, emphasis added) to student responses, or teachers placing "*less emphasis on* … textbooks" (NRC, 1996, p. 224) may send mixed messages to teachers especially new or beginning teachers regarding their role in the development of fundamental literacy skills. The nature of these messages may inadvertently imply that science education can and should be taught without instruction or development of fundamental science literacy.

The implicit nature and negative statements of fundamental science literacy messages along with the overwhelming presence of messages may contribute to teachers overlooking or viewing fundamental science literacy as not as important, or as second nature to skills associated with the derived sense. This resonates with research that describes traditional definitions of the way in which science teachers view, or understand science literacy. In the past, notions of what it means to be science literate have centered upon the derived sense of science literacy the ability to know the science content, to think problem solve and reason as a scientists (Norris & Phillips, 2003). To view fundamental science literacy as second nature to science content, science reasoning and science problem solving is problematic in that to perform such derived literacy skills one must be able to read, write, and orally communicate. Indeed, “If we wish students to gain insights and understanding of the manner and nature of scientific reasoning, we must offer them opportunity to use and explore that language” (Osborne, 2002, p. 204). In short, teachers can no longer view science literacy as separate from reading, writing, and oral communication. Fundamental science literacy skills must become perceived as central or corollary to the development of science literacy.

Science teacher educators also have the responsibility to influence the way science teachers view the development of the fundamental sense of science literacy within the classroom. If science teachers are to change their understanding or views regarding the fundamental sense of science literacy, science teacher educators must reassess their own views and teaching practices. Science teacher educators must consider how they use science reform documents within their classes and help beginning teachers understand the necessity of explicitly attaining to both derived and fundamental literacy messages.

*Conclusion*

This research has argued that fundamental science literacy messages are present within key science reform documents. Consequently, science educators and science teacher educators need to reassess their responsibilities in supporting fundamental science literacy skills. It has also been argued in this thesis that the nature, placement, quantity, and negative literacy statements within these documents may have an impact upon how readers view, understand, and implement strategies to help support the development of fundamental science literacy skills within the classroom. Future research in this area will need to be conducted, particularly in how science teachers and science teacher educators read or use these documents the reform documents. Further research will also need to be conducted concerning how these key reform documents impact the development of state and district science standards and curricula. If the *National Science Education Standards* (NRC, 1996) and other prominent science reform documents such as *Science for All Americans: Project 2061* (AAAS, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993) act as frameworks or guidelines for state and district standards and contain relatively few explicit or even implicit references to reading, writing, and communicating in and about science, then can we also expect that these messages will continue to be discarded, overlooked, or underemphasized in science classrooms nationally?

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