ANATOMY OF JUNIOR HIGH SCIENCE TEXTBOOKS: A CONTENT ANALYSIS OF TEXTUAL CHARACTERISTICS

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by

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Abstract

The purpose of this descriptive study was to determine the textual characteristics of junior high science textbooks, focusing on text type, truth status, metalanguage use, scientific status and role in scientific reasoning. Two textbook series were selected for analysis. Samples, representing ten percent of a life science and a physical science unit, were randomly selected from each textbook and analyzed. Popular reports of science were similarly analyzed to provide a comparative base.

The general findings are: (1) the text type is overwhelmingly expository with no evidence of argumentation; (2) both forms of scientific writing are largely written as "true," but textbooks present scientific knowledge as less textured and more "true"; (3) textbooks have only one-third the metalanguage use of popular reports of science; and (4) the majority of statements are facts or conclusions. The differences found between the two forms of scientific writing are discussed in light of the goal of scientific literacy.

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CHAPTER ONE

Purpose of the Study

Textbooks continue to play a fundamental role in science classrooms, often determining the science curriculum and dictating the mode of science instruction. Teachers rely on the student's ability to read and construct meaning from the textbook in order to gain understanding of science. Thus, science reading is a crucial part of the development of scientific literacy. Reading of science also provides the most likely avenue through which adults can continue to learn science and remain scientifically literate. Yet, research indicates that students, having completed high school, have difficulty accurately interpreting aspects of science texts (Norris & Phillips, 1994a). This paper will consider the question, "If science textbooks are the fundamental tool used in training students to read science text, are there characteristics of textbooks that might hamper the student's ability to construct meaning and develop an appropriate understanding of the knowledge, nature, and processes of science?"

The study is focused specifically at the junior high school level because it represents a crucial transitional stage in the education system, especially in the area of science. In the age range of 10 – 14 years, important conceptual foundations for learning science are established. Students become abstract thinkers and begin to construct initial mental models of major science concepts (Glynn & Takahashi, 1998). As well, as students prepare to enter senior high school, they must make many important decisions concerning their education. For some, their decision will be to discontinue formal education entirely as they drop out of school. For most, however, the key decisions to be made involve determining the number and type of courses to take and their career paths. It is at the junior high school level that many students lose interest in science or develop the view that science is too hard. These students choose to pursue a minimum number of science courses or limit their science exposure. For example, biology and earth science, being more descriptive and less mathematical than chemistry or physics, have traditionally been the courses of choice for students wishing to satisfy a science requirement with the least risk to their grade average (Shamos, 1995). If the education system is to provide the basic skills and knowledge needed for all students to become scientifically literate, which is a fundamental goal of science education, junior high school needs to become a focus.

The specific questions addressed in this study focus on the following textual characteristics: text type, truth status, scientific status, and role in scientific reasoning. A discussion of each textual characteristic follows separately. Included is a brief description or definition, the findings within science education research that motivates its investigation, and the specific question to be addressed.

Text Type

Texts often are placed into four categories: narrative, descriptive, expository, and argumentative (Moore, 1988). These text types will be explained more fully in Chapter Two. Different types of texts have different structural, lexical, semantic, and syntactic features and make distinct demands upon readers as they interact with the text in order to construct meaning. The text type impacts the readers' cognitive processing and learning (Brewer, 1980; Flood, 1986; Spiro & Taylor, 1987). It is suggested that differences in text type also result in differences in students' declarative, procedural, conditional, and metacognitive knowledge (Craig & Yore, 1995).

Science writing is a mix of the four types of text. Science generally describes and explains patterns of events that are not part of normal daily discussions. Science writing utilizes unique combinations of semantics, lexicon, syntax, and logic that influence comprehension (Yore & Shymansky, 1991). Science text often has terse expository patterns written in a relatively complex style, using many unfamiliar conceptual and process words (Holliday & Braun, 1979). In addition, students do not seem to know how to read and study expository text effectively (Armbruster, 1991; Baker, 1991). Both adults and children tend to have greater difficulty understanding expository text, such as science reading, than narrative texts, such as novels. Norris and Phillips (1994a) also found that students were not adept at using the metalanguage of science, such as "justification," "evidence," and "conclusion," to interpret the argumentative structure of science. Yet, exposition and argumentation are fundamental to the epistemic nature of science.

Given the unique demands of text types, the study will investigate the text types used in textbook presentations of different branches of science. Based on research findings, to be described in chapter two, and my exposure to science textbooks while teaching junior high science, I expect physical science topics to be largely expository and life science topics to be largely narrative, with some descriptive text in both. I also expect to find very little argumentative text in either branch of science, but especially life science topics. The study addresses the following question:

1. In junior high school science textbooks, what proportion of physical science and life science topics are written using expository, argumentative, descriptive, and narrative text?

Truth Status

Scientists make judgments of truth that are fallible and assert statements with different degrees of certainty, from complete uncertainty to certainty. Even when statements are declared to be certain, this declaration is taken as fallible. Research has found that students have difficulty accurately assessing the expressed certainty of science writing. Norris and Phillips (1994a) asked students to answer questions on popular reports of science in which the statements presented a wide range of certainty. The results indicated that students have a certainty bias, interpreting statements as being more certain than their authors had written them.

Shamos (1995) contends that there is a popular belief that scientific judgments are black or white and that science deals with hard facts, logical reasoning, and unequivocal judgments. One possible explanation for such a view is that it is a product of science education programs. Students are being trained to view science as truth. It has been argued that school textbooks create a context in which scientific phenomena are presented as facts or unshakable truths (Koulaidis & Tsatsaroni, 1996; McGinn & Roth, 1999). Limited by time and student interest, textbooks present conclusions without proof and imply that statements are to be accepted without question (Shamos, 1995). This study investigates the following question:

> 2. On a five-point scale, from "false" to "true," what proportion of statements in junior high school science textbooks fall in each category?

Taken in their entirety, even statements that express doubt are presented as true. For example, consider the sentence: "It may be that all living things have built-in clocks." It is true that all living things *may* have built-in clocks, but the writer is not attempting to portray a mood of certainty or truth, but one of uncertainty. The writer is expressing uncertainty about the fact that "all living things have built-in clocks." In this study, statements will be extracted from the text such that they will be in indicative mood and that modalities and intentionalities will not be indicated explicitly. For the example, the extracted statement would be "all living things have built-in clocks." The truth of this statement is presented as more uncertain. Extracting statements in this way, it is my expectation that the vast majority of statements in the junior high science textbooks will fall in the top category, "true."

Metalanguage

Scientific knowledge is structured in the sense that not all scientific statements have the same epistemic status and role in scientific reasoning. There is an extensive vocabulary, or metalanguage, which helps indicate the structure of scientific knowledge. This metalanguage includes terms such as "law," "cause," "observation," "method," "justification," "evidence," "conclusion," and so on. The metalanguage of science assists the reader in determining a statement's status and role in scientific reasoning and laying a foundation for the critical interpretation of science text and the construction of meaning.

Textbooks have been criticized for their use of metalanguage. For example, textbooks often project "theory" as being a fanciful speculation that need not be taken seriously, which is the very opposite of its meaning in science. It is important that textbooks use metalanguage in such a way as to portray an accurate view of the nature of science and to make the structure of scientific knowledge explicit. This study, then, addresses the question:

3. In junior high school science textbooks, what is the frequency per line of metalanguage use, including such categories as " observation," "method," conclusions," etc.

In chapter three, I will define the specific range of metalanguage categories to be examined. I expect "observation" and "method" to be widely used.

Scientific Status and Role in Scientific Reasoning

As mentioned earlier, the metalanguage of science helps indicate the structure of scientific knowledge by revealing the scientific status and role in scientific reasoning of the statements made. Norris & Phillips (1994a) found that students did not accurately interpret several aspects of the underlying structure of science and the implied authorial intentions in popular reports of science. For example, students had difficulty identifying statements of causation, justification, and evidence. Students were also less able to infer the role of statements in scientific reasoning when contextualized interpretation on the basis of perceived relationships among statements was required. One possible explanation is that students have not been taught to interpret the semantic or logical connections in science text, a skill that is key to scientific understanding.

Textbooks have been criticized for their poor distinction of scientific status statements. They conflate observations, inference, and theory and present information as if it were final, immutable truth that has come out of nowhere (Lerner & Bennetta, 1988). Thus, both students' tendencies to overestimate the truth of scientific statements and their inability to identify and connect statements of scientific status may be a result of exposure to science textbooks that poorly portray the structure of scientific knowledge. The fact that students have difficulty differentiating particular aspects of the structure of scientific knowledge (causation, evidence, justification, and conclusions) raises an additional question:

4. In junior high school science textbooks:
   A. what proportion of the text reflects various types of scientific status statements?
   B. what proportion of the text reflects statements playing various roles in scientific reasoning?

CHAPTER TWO

Review of Related Literature

The purpose of this chapter is to review the literature pertaining to the role of textbooks in the development of the student's ability to read and accurately interpret science text. It begins with a discussion of scientific literacy, the primary goal of science education today, and then discusses aspects of text structure and organization that impact reading and understanding. Particular attention is focused on text types and the structure and organization of science textbooks. The importance of science textbooks, both as the primary instructional tool in science classrooms and as the student's principle source of science reading, is also highlighted.

In the ideal, when science text is written, the author intends for the reader to obtain a particular meaning and understanding which is scientifically accurate. An important part of reading is the recognition that there is an intended meaning and the use of print cues and context to infer this meaning. Thus, a discussion of meaning, both literal and inferential, is included. Reading, however, is a constructive process in which both student and textual characteristics come into play. If print cues are inaccessible, ignored, or absent, students may construct a meaning that is scientifically incorrect.

Students may have difficulty inferring the pragmatic meaning of a text if print cues are limited or absent. Pragmatic meaning refers to the meaning in relation to the intentions of the writers and the context of language use. An important print cue in science is the use of metalanguage, such as "observation," "conclusions," and "method." Metalanguage is especially important in assisting in the identification of a statement's scientific status and role in scientific reasoning. If metalanguage is limited, absent, or inaccessible to the student, the construction of scientifically accurate interpretations will be difficult. This study examines the metalanguage, the scientific status of statements, and the role in scientific reasoning of statements presented in textbooks. Thus, metalanguage, scientific status, and role in scientific reasoning are all pertinent topics to be reviewed.

Print cues may also be inaccessible to the students because they are unfamiliar with the text type or the text structure being used to present the information. The text structure and organization used in science textbooks have implications for science reading. Finally, students may ignore print cues if they point to a meaning that contradicts their present knowledge and views. For example, when scientific text is presented as uncertain, it has been found that students interpret the information as being certain, despite the print cues that would indicate otherwise. Students' seem to have a view of science as being certain truth that overrides the print cues provided. Recognizing the textbook as a key source of prior knowledge concerning science, this study examines the truth status of science presented in textbooks. Thus, a discussion of truth status is included.

Scientific Literacy

I will discuss three aspects of scientific literacy. First, I will highlight scientific literacy as a principle goal of science education. Second, I will examine many definitions proposed for what scientific literacy is. Finally, I will show the significant connection between science textbooks, the focus of this study, and the goal of scientific literacy.

Scientific Literacy as a Goal of Science Education

Literacy is considered a necessary condition to functioning effectively as a contributing member of society. The past few decades have brought tremendous scientific and technological advancements and have led to an information explosion. Science has played a role in creating our greatest achievements and our greatest fears. The pace of technological change is so great that it is difficult to anticipate how best to prepare students for the future. The certainty that existed in the past, that the education system was providing citizens with the skills and knowledge needed, no longer applies. This reality creates new challenges for science education and educational reform (Cross, 1995). In light of this reality, reform proposals have advocated the development of general, rather than specific, scientific skills, attitudes, and knowledge. Scientific literacy, then, has become one of the primary goals of high school science education (Eisenhart et al., 1996; Gibbs & Lawson, 1992; McGinn & Roth, 1999; Norris & Phillips, 1994a; Zimmerman et al., 1998). Science education endeavours to cultivate the desire and skills for lifelong learning in science, rather than solely preparing future scientists for their careers.

Science is highly valued by our culture (Segal, 1997) and scientific literacy is viewed as the educational solution to numerous societal problems. These include the low level of scientific knowledge among members of the population, the poor teaching of science in schools, the disproportionately low percentage of women and minorities in many science fields, and the inability of many citizens to use scientific knowledge to make decisions that affect their lives (Eisenhart et al., 1996). National destiny is seen as being increasingly dependent on participation in the technological revolution. Science education, then, is viewed as a national investment for the promotion of a technological society (Cross, 1995). The students of today will be the citizens of tomorrow. They will be called upon to make personal, professional, and public policy decisions that require an evaluation of scientific findings and the ability to separate technical aspects of these decisions from the political and moral ones (Zimmerman et al., 1998). Science has played a role in creating problems that cannot be dealt with by scientists alone. The promise of a prosperous, socially compassionate and responsible democracy lies in the development of a scientifically literate population (Glynn & Muth, 1994; Rutherford & Ahlgren, 1990). Ignorance of science and technology has become a self-indulgent luxury (Bernstein, 1984).

The fact that there is no single definition of scientific literacy has not lessened its importance as a central goal of education. Although many definitions have been proposed, there is remarkable agreement that scientific literacy is a broad and inclusive vision, promising widespread use and requiring much more than scientific knowledge in the formal academic sense (Eisenhart et al., 1996; Shamos, 1995). The goal of scientific literacy has received unequivocal support, although there are doubts that this goal can be reached within the present science education curriculum. Reform agendas have resulted in science education that continues to focus on key concepts and conventional science practices, but this does not seem to be producing the desired results. Despite the investment of massive amounts of money, time, and effort, little overall change in scientific literacy has been found (McGinn & Roth, 1999). Shamos (1995) contends that the average citizen's knowledge of science is less today than at any other time since science became a part of the school curriculum. The depth and breadth of science has increased so dramatically that the problem of assisting citizens in better understanding science has become compounded. As well, research has discredited the assumption that an educational program focused on key concepts and conventional science practices leads to socially responsible uses of science or to participation by a larger and more diverse citizenry (Eisenhart et al., 1996). School science is often disassociated from the everyday experiences of the students, resulting in a lack of appreciation for science or understanding of science. The education system has been criticized for its failure to keep pace with:

> the nature of contemporary research in science, the increasingly more holistic view of science, the influence of technology upon science, the integrated nature of science and technology ... [or] with changes in society, including how citizens both acquire and use knowledge (Kyle, 1995, p. 1007).

If the goals associated with scientific literacy are reached, it will profoundly change the capabilities of our society. In order to reach these goals, however, the education system that created the problems must be involved in the solution (Wright & Wright, 1998). Science education will need the public's appreciation and support and will need to establish the importance of remaining literate in science. Kyle (1995) contends that what is needed is widespread acceptance of the idea that becoming and remaining scientifically literate is in one's self interest.

Definitions of Scientific Literacy

As mentioned earlier, there is no single definition of scientific literacy. Suggested components include the ability and willingness to continue learning science, the development of scientific processes and a contemporary view of science and the ability to communicate ideas to others effectively (Holliday et al., 1994; Sutman, 1996). The Council of Ministers of Education Canada (1997) have also identified an attitudinal component as foundational to scientific literacy. Garcia (1985) examined the work of many science education researchers and organizations to form broad and discrete categories of scientific literacy for her analysis of the presentation of scientific literacy in earth science textbooks. This examination resulted in four categories of scientific literacy: a) The basic knowledge of science; b) the investigative nature of science; c) the thinking process of science; and d) the interaction of science, technology, and society. These same categories were adopted by other researchers examining the presentation of scientific literacy in textbooks (Chiappetta et al., 1991; Chiappetta et al., 1993). These themes also reflect the most current trends in science education reform as found in national science reform proposals in the United States, such as Project 2061 and the National Science Education Standards, in the British National Curriculum, in a number of Canadian provincial curricula, and in the new Spanish and Danish curricula (Matthews, 1998; Lumpe & Beck, 1996).

Traditionally, knowledge of a wide range of science information has been emphasized within science education. While this knowledge is still considered important, the recent reform movement has espoused the view that science subject matter should be focused on broad themes of science. They argue for greater depth of understanding of a few key concepts rather than having breadth of coverage with only cursory knowledge (Lumpe & Beck, 1996). Shamos (1995) argues that "contrary to what most science educators contend, knowing science in the formal academic sense may not be a necessary condition to attaining scientific literacy in the social sense. However, knowing what science is about is prerequisite to such literacy" (p.45). Shamos proposes a definition of scientific literacy based on teaching science in order to develop appreciation and awareness of the enterprise rather than for content, focusing on technology as a practical necessity, and emphasizing the proper use of scientific experts for the development of social literacy. Based on these ideas, scientific literacy would mean having an awareness of how the science/technology enterprise works, feeling comfortable with knowing what science is about, understanding what can be expected from science, and knowing how public opinion can best be heard in respect to science and technology.

Glynn & Muth (1994) also emphasize that scientific literacy is more than just science knowledge. To be scientifically literate, "students also must have the reading ability to evaluate the print-based information presented to them and the writing ability to communicate their thoughts to others and have an impact on their thinking" (p. 1057-8). Norris and Phillips (2000) agree. They support the view that literacy has at least two senses, as described by Kintgen's (1988). In the descriptive sense, literacy refers to the ability to read and write and in the evaluative sense, literacy refers to the mastery of a body of knowledge. Norris and Phillips (2000) argue that these two senses of literacy result in two distinct educational goals for science: the goal of mastering the content of science and the goal of teaching students how to read and write when the content is science. The failure to attend to either goal would be a serious loss to science students. They state that "reading and writing are inextricably linked to the very nature and fabric of science, and by extension to learning science, " (p.7) and thus "being literate in science means being able to interpret accurately scientific text" (p.13). Hanrahan (1997, December) views science learning as language learning and science teaching as literacy teaching. The ability to read, understand, and critically assess material from the various genres of science literature encompasses the common elements found in definitions of scientific literacy discussed earlier. Students require knowledge of science information, the investigative nature of science, the thinking process of science, and the interaction of science, technology and society. Thus, the skill of reading and evaluating science text can be seen as "a valuable capstone index of scientific literacy" (Zimmerman et al., 1998).

In their examination of national science reform proposals, Eisenhart et al. (1996) found remarkable agreement that scientific literacy is a broad and inclusive vision, requiring much more than a familiarity with scientific facts. The image of scientific literacy implies the ability to act, using scientific knowledge and ways of thinking for individual and social purposes. In fact, a recent document released by the National Academy of Sciences, providing national standards for K-12 science education, defines scientific literacy in terms of what a scientifically literate person is capable of doing. These abilities include being able to: describe, explain, and predict natural phenomena; read, with understanding, scientific articles in the popular press; and consider the source and methodology by which scientific information is generated in order to evaluate the quality of the information (Hinman, 1998). Glynn and Muth (1994) argue that "without scientific literacy, it is difficult to make informed decisions about the interrelated educational, scientific, and social issues that one confronts every day" (p. 1057-8).

The framers of the national standards expect that successful implementation of the standards will result in the development of attitudes and skills all students will need for success in life. Students will develop the skills needed to connect abstractions with the concrete world. They will take ownership of their learning, incorporating what they learn into everyday skills. The central strategy for bringing about these changes is to engage students in meaningful inquiry (Wright & Wright, 1998). Genuine inquiry provides the perspective and insights needed to help scientific ideas become part of a person's usable knowledge and skills (Newmann, 1991). Inquiry is at the core of science and, thus, is a central aspect of scientific literacy (Staver & Bay, 1987).

McGinn and Roth (1999) feel that the implemented changes in science education have not been successful because they have been built upon mythical views of science and scientists that have been discredited by recent research. Scientific knowledge is now viewed as far more complex and tenuous than originally thought. Scientific research and its products are recognized as situationally contingent achievements, created and used by heterogeneous groups of people across diverse settings. McGinn and Roth (1999) emphasize that "science education needs to look toward new educational aims that reflect the situated, contingent, and contextual nature of science, while also acknowledging the diverse range of communities and locations where science is created and used" (p. 17). They see scientific literacy as empowering people to engage in the discourses and practices of science, which requires an ability and willingness to reflect on the fallible and contingent nature of science and scientists, the heterogeneity of science, and the positive and negative aspects of science. Similarly, Hanrahan (1999) makes a case for seeing literacy as "being willing and able to participate authentically in the social practice of a particular community" (p.699). In their view, the result of implementing such a vision of scientific literacy would be a critically engaged citizenship who are competently participating in the many communities where science is created and used.

While the national standards emphasize scientific literacy for all, scholars in the areas of multicultural education, feminism, religion, environmentalism, and sociology and philosophy of science have challenged the basic notion of science and the meaning of scientific literacy. They feel that scientific literacy is generally defined in the Western science tradition and that this may have serious negative impacts with students from diverse cultures and languages. Students from non-Western cultures may have ways of knowing and thinking that are incompatible with, or even contradictory to, the Western science tradition and mainstream cultural norms. This makes the challenge of developing scientific knowledge and habits of mind even greater (Lee, 1997; Matthews, 1998). Segal (1997) suggests that canonical approaches implicit in authentic school science can be tempered by framing school science through personal, social, historical and cultural values. This approach would also provide a broader framework for recognizing the values of canonical approaches to science.

It is unlikely that one definition of scientific literacy will be agreed upon. Sfard (1998) suggests the use of metaphors to provide a framework that allows for dialogue about the differences. He suggests two metaphors of learning that reflect upon the vision of scientific literacy. The first, learning as acquisition, would suggest that the ability to access the canonical knowledge of the scientific community is a crucial aspect of scientific literacy. The second metaphor, learning as participation, views scientific literacy as being able to conceive, debate, and communicate ideas about phenomena. Sfard (1998) emphasizes, however, that the vision of scientific literacy should never rest upon any one metaphor since "theoretical exclusivity and didactic single-mindedness can be trusted to make even the best of educational ideas fail" (p. 10).

Eisenhart et al. (1996) argue that, despite disagreement concerning the definition of scientific literacy or the means by which scientific literacy can be reached, scientific literacy should remain the abstract image that guides science education reform. They point out that it sets a high and desirable ideal standard for education. The definition of scientific literacy is subject to change since it is a social achievement that varies and evolves with location, time, and social purposes, but "regardless of definition or metaphor, the image of literacy suggests the ability to act and the promise of widespread use" (p. 282). Wright and Wright (1998) emphasis that a clear vision is needed of what scientific literacy means and what it will look like when it is reached. Otherwise, "[if] the vision is not clear, the implementation will fail" (p. 125).

Scientific Literacy and Science Textbooks

Scientific literacy has become the fundamental goal of science education. It guides and directs science education and also the development of teaching tools, such as science textbooks. Most of the textbooks being introduced into science education now state that scientific literacy is a major goal. For example, this study focuses on two junior high school science textbook programs: *Science Directions* (1991) and *SciencePlus Technology and Society* (1989). Both of these textbook programs, which include textbooks for Grades 7-9, have been written with the goal of scientific literacy in mind. Although *SciencePlus Technology and Society* (1989) does not explicitly state that scientific literacy is its guiding philosophy, it does state that it "supports the aim that all individuals should be able to play an active role in science and technology, and that all students should find science valuable and enjoyable" (p. vi). These are key components of proposed definitions of scientific literacy. *Science Directions* (1991) more explicitly states the importance of scientific literacy to the development of the program:

> Science educators all over the world are being challenged to rethink the goals, purposes, and processes of science teaching. The importance of scientific literacy for all citizens has become increasingly clear...*Science Directions* responds to these new challenges...*Science Directions* provides a balanced approach to science by emphasizing three important goals of science education in each book. Some units concentrate on the nature of science and science processes. Others place their main emphasis on the relationship between science and technology. And still others expose students to science-technology-society (STS) understandings (p. ix)

The science textbook remains the fundamental tool used in science education. Textbooks shape the curriculum and the mode of instruction, and affect the students' perceptions of the scientific enterprise. The textbook provides a blueprint from which students develop their views of science and technology. Therefore, textbooks are a critical factor in the development of scientific literacy. It is important that textbooks accurately reflect the themes of scientific literacy that are believed to be important.

Many commercially available textbooks have been criticized for their presentation of the scientific enterprise. For example, many textbooks present science as a complete body of information that was derived in an errorless manner (Chiappetta et al., 1991). Some textbooks focus on science as a body of knowledge, to the near exclusion of themes such as science as a way of investigating, science as a way of thinking, and the interaction of science, technology and society. These textbooks hinder, rather than aid, the development of scientific literacy. A well-written textbook, however, can familiarize the student with the conceptual relations that form the basis of real scientific expertise and understanding, leading to scientific literacy. Glynn & Muth (1994) note that "students who are learning constructively will challenge the science text they are reading or writing, struggle with it, and try to make sense of it by integrating it with what they already know" (p. 1060). Being able to read and understand the science textbook, then, is a critical part of being scientifically literate.

Science textbooks also provide the avenue for continued life-long learning in science. Upon completion of formal schooling, individuals will only be able to keep abreast with the constantly changing world of science through the processes of reading and writing, as they interact with all types of print, from textbooks to computer screens (DiGisi & Willett, 1995). Learning from traditional and electronic scientific texts is an important method of achieving and maintaining scientific literacy (Yore et al., 1998). Developing a fundamental grasp of reading and understanding science text is a critical part of enabling people to remain scientific literate. The ability to critically evaluate media reports is crucial to making informed decisions about interrelated educational, scientific, and social issues (Zimmerman et al., 1998). Thus, the fundamental aspects of the image of scientific literacy depend on the development of the ability to read and understand science. The development of this ability, which relies on an understanding of the structure and organization of science text, begins with formal education and the science textbook.

Summary

In light of the incredible pace of scientific and technological advancement, scientific literacy has become the primary goal of science education. Focused on general knowledge, skills, and life-long learning of science, scientific literacy for all is seen as the best way of ensuring that students have what they need to be successful in the future and to ensure a prosperous national destiny. Scientific literacy is also seen as the solution to many of the present societal problems connected with science and science education. Numerous definitions or components of scientific literacy have been proposed. They include: a knowledge of broad themes of science; an understanding of the nature of science and scientific processes; an appreciation of the interaction between science, technology, and society; a willingness to continue with life-long learning in science; and an ability to interpret scientific text and communicate effectively about science.

Scientific literacy is generally viewed as a broad vision that implies the ability to act and use scientific knowledge and ways of thinking for individual and societal purposes. The development of scientific literacy is seen as the development of attitudes and skills needed to succeed in life. Concerns have been raised, however, that scientific literacy has been defined in such a way as to alienate students of non-Western cultures and languages, thus limiting the likelihood of reaching the goal of scientific literacy for all. As well, significant changes to the present science education system appear to be needed in order to reach the goal of scientific literacy. Although there is disagreement about the specifics of what scientific literacy entails, there is little argument about whether or not it should be the vision that guides science education reform.

Textbooks are a critical factor in the development of scientific literacy since they are the fundamental tool used in science classrooms, shaping the curriculum and the mode of instruction. Being able to read and understand science textbooks is crucial. It assists students in becoming scientifically literate. It also provides an avenue by which people can become life-long learners of science and remain scientifically literate.

Given the profound influence that textbooks have, it is important that textbooks be examined and evaluated before being used. Textbook analysis has become a significant area of educational research. This study examines two junior high school science textbook series – *Science Directions* and *SciencePlus Technology and Society* - which are the textbooks of choice for several provincial science curricula in Canada. It examines the text structure and organization, which can have a profound effect on a reader's ability to learn from science text and affects the likelihood that the goal of scientific literacy will be reached.

Text Structure & Organization

Text organization includes the purpose of materials, the arrangement of ideas, and the choice of rhetorical patterns utilized to show relations between ideas. Text organization encompasses characteristics of the text such as cohesion, explication, conceptual density, metadiscourse, writability, and instructional devices (Barba et al., 1993; Spiegel & Barufaldi, 1994). Organizational relations are expressed through content words and organizational devices, such as levels of headings.

Text structure and text organization have a great impact on the reader's comprehension. The features of the text can affect the degree to which readers engage in cognitive processes needed for meaningful learning (Mayer et al., 1995). A reader's interpretation can be triggered by the overall text structure and by language cues embedded in the text. Good readers pay attention to hierarchical text structure and passage organization to learn from text (Alexander & Kulikowich, 1994). Recent studies suggest that as students read text they must organize the ideas in a logical fashion. Students either choose the structure employed by the author or impose one of their own. Ideally, the text introduces an organizational structure that is understandable and usable by the student and improves on the explicit structure in the student's mind. Science content is most efficiently stored in memory when the writer's organizational structure is used by the reader (Glynn & Muth, 1994; Holliday & Braun, 1979).

An important part of a text's structure and organization is the text type utilized. In this section, a discussion of the types of text and their characteristics is included. Science textbooks present a unique combination of text structure and organization, thus creating unique challenges for the reader. This section also includes a discussion of the characteristics of science textbooks and the implications of the structure of science textbooks for the reading and understanding of science.

Text Type

Text types represent groupings of texts that are similar in linguistic form or pattern, regardless of genre (Paltridge, 1996). There are four general types of text. *Exposition* presents facts or explains why something is important, how something works, or what something means. The purpose of exposition is to inform the reader. For example, science text that explains how the principle of electromagnetic induction is involved in a motor or generator would be expository. *Argumentation* uses information to support or test a belief for the purpose of convincing the reader. For example, research findings can be presented that suggest a negative impact on the environment due to increasing pollution levels and the greenhouse effect. This information can be used to convince people of the need for concern about global warming and to take appropriate measures to reduce pollution levels. *Narration* relates action or tells some kind of story as it chronicles an experience or series of events. A science text that chronicles the life and research of a scientist would be an example. *Description* provides visual details that enable the reader to see an object, person, or scene as the author has seen or imagined it (Moore, 1988). For example, a description of the model of the atom could assist students in their understanding of the chemical interaction of matter. An extended text may utilize more than a single type of text. For example, description is often an important part of a narrative. Different text types also have identifiable rhetorical structures. For example, text structures of exposition can include time order, collections of descriptions, comparisons, cause and effect, problem-solution, general-particular, matching-contrast, and hypothetical-real texts (Paltridge, 1996).

A difference in text type can have a significant impact upon readers' understanding of the text. For example, narrative and expository texts have different lexical, semantic, and syntactic features that place different demands upon readers as they construct meaning (Craig & Yore, 1995). The purpose of the text and the developmental stage of the reader seem also to be factors in the reader's understanding of text. Studies have shown that high school students have a better chance of learning counterintuitive science concepts when they are presented in expository text, while elementary students seem more willing to give up their personal commitment to an idea when it is refuted in narrative text (Alvermann et al., 1995). However, it has been found that both adults and children tend to have more difficulty understanding and remembering expository text than narrative text (Armbruster, 1991).

It has been argued that students simply do not know how to effectively read and study expository text (Baker, 1991). One reason is that students do not practice reading expository text enough, resulting in a lack of experience with expository text (Armbruster, 1991; Craig & Yore, 1995). Insufficient instruction in how to read exposition also has an effect, suggesting that explicit instruction in the unique characteristics of expository text might improve reading effectiveness (Yore & Shymansky, 1991). In addition, children have difficulty reading expository text because they are unaware of text structure and organization. The text structures used in narratives, such as the use of vigorous active verbs and chronological order, are generally familiar to readers. The text structures of narration, however, differ greatly from those in exposition. With exposition, readers more frequently fail to grasp the gist of the text or the relationships between the ideas presented. Awareness of text structure can help the reader in the selection of relevant information and building internal connections (Cook & Mayer, 1988). Research has shown that students who are aware of text structure learn more from expository text than those who do not (Armbruster, 1991). Thus, recognition of text organization is an aid to understanding text and research has shown that the recognition of text structure can be taught (Speigel & Barufaldi, 1994).

Another reason for students' difficulties understanding expository text may be a lack of interest or motivation (Armbruster, 1991). Researchers have found, however, that improved readability leads to greater interest (Johnson & Otto, 1982). The key, then, is the students' development of knowledge and skills for reading expository text. Text learning is enhanced when students have knowledge of language conventions and knowledge of text structure. This knowledge can be established through explicit instruction and experience with expository text. Being able to interpret expository text is vital to understanding science and depends on an understanding of the assumptions, norms, and practices associated with exposition.

Science Textbooks

Textbooks play an integral part in science education. In fact, science textbooks are the ultimate source of science knowledge in many science classrooms (Alexander & Kulikowich, 1994; Barba et al., 1993; Chiappetta et al., 1991; Shamos, 1995). Textbooks shape the curriculum and dictate the mode of science instruction to the extent that, in many ways, they become the embodiment of school science (Chavkin, 1997; Chiappetta et al., 1993; Eltinge & Roberts, 1993; Glynn & Muth, 1994; Koulaidis & Tsatsaroni, 1996; Meyer et al., 1988; Musheno & Lawson, 1999; Ornstein, 1992; Staver & Bay, 1987; Yore, 1991). There is little to indicate that this reality is likely to change. In fact, the challenges faced by the education system, such as increasing class sizes, decreasing budgets for equipment and supplies, increasing safety concerns and aging teacher populations, will likely contribute to a continued dependence on textbooks (Farragher & Yore, 1997; Yore, 1991). Studies estimate that as much as 75% of classroom instruction and 90% of homework is structured around science textbooks (Lumpe & Beck, 1996; Spiegel & Barufaldi, 1994). Clearly, textbooks profoundly affect the learning experiences of students and their perception of the scientific enterprise (Chiappetta et al., 1993; Eltinge & Roberts, 1993; Ornstein, 1992).

Science textbooks rely more on exposition than most other school reading, which commonly rely on narration. Science textbooks contain common expository text structures, such as enumeration, generalization, sequence, classification, and comparison/contrast. Lack of familiarity with these aspects of science text can make learning more difficult. Research has found that even college-level readers do not possess fully developed concepts for expository text structures, tending to confuse enumeration, generalization, and comparison/contrast. Readers can, however, learn to become more effective processors of scientific text by learning active reading strategies (Cook & Mayer, 1988). The ability to recognize and utilize text patterns is an important part of obtaining a sound interpretation of text. Knowledge acquisition, then, depends on the skills and strategies students use to read and comprehend expository text (Spiegel & Barufaldi, 1994).

In comparison to other scientific writing, the reading difficulty of textbooks occupies a wide spectrum between that of popular articles and research papers. All textbooks, however, have approximately the same educational format. They are designed to be used interactively and include features to enhance comprehension. Objectives are clearly outlined and chapter overviews are provided. Textbooks include series of qualitative and semi-quantitative questions and exercises that assist the reader in testing his or her knowledge of specific chapter sections. There are also problem sections that contain series of exercises that span a number of sections and require synthesis of concepts (Mallow, 1991). Textbooks traditionally use organizational features, such as the table of contents, chapter titles, section headings, and the use of typefaces and type size, to guide the reader's learning (Walpole, 1998). Readers need to use these features as clues for building an understanding. For example, many students have learned to ignore headings in narrative text, whose purpose is mainly to titillate, rather than inform. However, to ignore the headings in science is to ignore the plot of the text itself. The headings in science text contain accurate, pertinent information, cover all the main points, and reveal a sequential, unambiguous logic (Young, 1992). For example, text under the heading "results" would provide a list of observations or findings. Text under the heading "discussion" would connect these observations to previous findings, make inferences of relationships, present how the results reflect on the hypothesis being tested, and discuss the significance of the relationships found to the reader or research area. Recognition of the unique characteristics of science textbooks can assist students in developing a better understanding of science.

There are several other features commonly used in textbooks that can assist readers in their construction of meaning, if used appropriately. One is the presence of illustrations. Much of science lends itself to visual representation, making illustrations essential to the reading process (Mallow, 1991). Research has found that annotated, multi-frame illustrations greatly improve the understanding of a cause-and-effect system. Used in this way, illustrations can effectively promote problem-solving transfer. Yet, despite the devotion of one-third to one-half of the space in science textbooks to illustrations, many textbook illustrations do not seem to serve an important instructional function (Mayer et al., 1995). This suggests that modest modifications in the way illustrations are presented could greatly improve students' comprehension. Another text feature commonly used is the analogy. The history of science and science education illustrates the important role that analogies can play in explaining fundamental concepts. Analogies continue to be frequently used in science textbooks to help explain points. Analogies can help students build meaningful relations between their prior knowledge and a new learning experience, compatible with a constructivist view of learning (Glynn & Takahashi, 1998; Iding, 1997). Unfortunately, lacking guidelines for the effective use of analogies, authors' analogies are often ineffective and can lead to misconceptions and confusion. Research, however, has begun to provide such guidelines. Analogies can be very effective in promoting learning, especially for novices. Analogies used for instructional purposes usually involve the presentation of an abstract new concept (target domain) with a concrete, familiar concept (base domain) to help students conceptualize the new concept. Characteristics of a good analogy include the use of a familiar base domain, having multiple features of the base and target that can be mapped, and using features that are similar enough that the mapping can be carried out without confusion. To avoid misconceptions, the limitations of analogies should always be pointed out

(Iding, 1997). Providing explicit instruction on the use of illustrations and analogies can assist students in the effective use of science textbooks and enhance science learning.

Textbooks provide the blueprint from which students construct their initial understanding of science. As such, it is of vital importance that science textbooks be both accurate and well written. Many educators, however, criticize textbooks for their presentation of science. Textbooks often present enormous amounts of information (Chiappetta et al., 1993; Linn et al., 1989; Ornstein, 1992) and in so doing may provide only a superficial coverage that discourages conceptual thinking, critical analysis, and evaluation. By its structure, the textbook defines science as a collection of facts, rather than a dynamic process of discovery and theory generation (Gibbs & Lawson, 1992; Jabion, 1992; Musheno & Lawson, 1999). Textbooks have also been criticized for presenting information in a piecemeal, incoherent manner, leaving readers with inaccurate or incomplete interpretations (Alexander & Kulikowich, 1994). Yager (1983) reviewed twenty-five of the most commonly used science texts in K-12 classrooms and found that more new science words were introduced in these texts than foreign language words introduced in foreign language texts. Scruggs (1988) found the same pattern in junior high science texts, which introduce as many as 2500 technical terms and unfamiliar words. Among the corpus of technical terms introduced are many words that have precise meanings and which differ from those used in everyday speech (Daniels, 1996). This is alarming for educators who are interested in promoting meaningful learning. Not only does the sheer amount of new information and vocabulary make understanding difficult for most students, it especially affects students who are low verbal learners or have limited proficiency in English (Barba et al., 1993).

Recognizing the significant role that science textbooks play in creating the students' views of the nature of science, it is important that textbooks reflect the themes of scientific literacy that are believed to be important. These include science as a body of knowledge, science as a way of investigating, science as a way of thinking, and the interaction of science, technology, and society. Research indicates, however, that large portions of science textbooks reflect science as a body of knowledge, to the virtual exclusion of science as a way of thinking and the interaction of science, technology, and society (Chiappetta, 1993; Hamm & Adams, 1988; Lumpe & Beck, 1996; Staver & Bay, 1987). Discussions of the processes of science and scientific thinking are often limited to a few pages at the beginning of the book, under the heading of "scientific method." Inconsistencies in the definitions and use of terms, such as "hypothesis," "prediction," and "theory," were found to be common among textbooks, and even among different sections of the same textbook. This finding is the basis for the opinion expressed by Gibbs & Lawson (1992) that "if being scientifically literate means understanding how one does science, we would have to conclude that many authors of introductory textbooks are scientifically illiterate as well" (p.151).

When present, the four major themes of scientific literacy are presented in isolation rather than being integrated to display the holistic nature of science (Gibbs & Lawson, 1992; Lumpe & Beck, 1996). Scientific inquiry is occasionally present in its most limited form in textbook activities, but the majority of lab activities are simply cookbook in nature, and inquiry is absent (Lumpe & Beck, 1996; Musheno & Lawson, 1999; Staver & Bay, 1987). Relying on the presentation made by textbooks, students will develop an incomplete and inaccurate view of the nature of science. Scientific literacy depends on having an accurate understanding of the nature of science, which perhaps is the reason a heavy reliance on textbooks does not appear to produce the desired states of effective science instruction or scientifically literate graduates (Lumpe & Beck, 1996; Yore, 1991). Wright and Wright (1998) contend that:

> the universe provides the incentive and inspiration for learning. Self-discovery and creation build a respect and love for the universe that cannot be attained by passive activities. We can never destroy what we have come to love and respect. If we insist on teaching content and do not include the experiences that build the values of beauty and soul, the content will not be permanent. There will be little of importance that remains (p.140).

There have been inconsistent findings concerning science textbooks. Teachers often express concern that textbooks are too difficult for their students. Factors that are believed to have an impact are the state of readiness of the students, their background experiences, their intelligence and maturity, the readability level of materials, and the level of sophistication of the material (Vachon & Haney, 1991). Yet, research has found that interviewed teachers have described the reading level of textbooks as "about right" for the majority of the students in the class at each academic level (DiGisi & Willett, 1995). Some studies have found many examples of science textbooks that were not "reader-friendly", based on structure, coherence, unity, and audience appropriateness, while other studies found very few examples of such textbooks. This may be a result of the substantial differences in readability, content and pedagogy found across content domains and between textbook programs (Eisenhart et al., 1996). It is crucial, then, that science educators evaluate and select science textbooks carefully. There is also evidence that publishers are making the effort to change textbooks. Many new science textbooks aspire to match trade book models, as information books have become the fastest growing new area in children's publishing. Walpole (1998) examined two textbooks published by the same publisher, one published in 1992 and the other in 1995. The study found significant differences in structure and organization between the two texts. The newer text also asks the reader to do or think something more often, speaks directly with the reader and directs personal connections and cognitive reflections. In this way, it encourages the reader to take responsibility for making meaning and integrating text ideas with prior knowledge. As this is more in line with the interactive-constructive view of science reading, these changes are encouraging.

Science Reading

The connection between science learning and science reading is a little studied topic (Yore, 1991; Yore & Shymansky, 1991) and yet reading is one of the most frequently used forms of science instruction reported by practicing science teachers (Craig & Yore, 1995; Yore, 1991; Yore et al., 1998; Yore & Shymansky, 1991). Reading science text is seen as an essential component of doing science (DiGisi & Willett, 1995). Students, then, must have the reading ability to interpret the print-based information presented to them. They also require the reading ability to keep up with changing scientific knowledge as they continue their life-long learning of science through science text. The ability to deal with science-related issues that arise in the future will require knowing how to read and understand science text. Thus, to be scientifically literate and to maintain scientific literacy, reading is a crucial life-skill (Gaskins et al, 1994; Yore & Shymansky, 1991). Scientific literacy cannot occur outside of general literacy since being able to understand and explain fundamental scientific concepts is central to scientific literacy and is dependent upon the ability to read science text effectively (Glynn & Muth, 1994; Sutman, 1996).

An important advancement in science reading has been the reconceptualization of reading as an interactive-constructive process, recognizing the importance of experience, language, and thinking. This model is also philosophically compatible with the current constructivist models of science learning and current philosophies of science (Glynn & Takahashi, 1998; Holliday et al., 1994; Stein & McRobbie, 1997; Yore et al., 1998; Yore & Shymansky, 1991). Reading is viewed as the active construction of a text's meaning, involving an interaction between writer and reader. Both science reading and science learning, then, are complex undertakings involving the knowledge and interests of the learner, characteristics of the text, science reading strategies, and the context of the reading (Alexander & Kulikowich, 1994; Craig & Yore, 1996; Holliday et al., 1994; Speigel & Barufaldi, 1994; Watters & English, 1995). This dynamic interplay can change significantly as a function of the scientific domain of study. For example, students may find biology easier to learn if they perceive it to be more personally relevant. This may also explain why many students find biology easier to learn than other subjects, such as physics (Alexander & Kulikowich, 1994). Biology is more likely to be seen as personally relevant.

The text acts as a blueprint, guiding the construction of meaning. It establishes broad limits of possible meaning, but does not specify a single meaning. The perception, storage, and retrieval of information are all constructive processes that are influenced by the students' expectations, beliefs, values, sociocultural background, and existing knowledge. Readers actively construct meaning as they access ideas using basic decoding skills and clues from the text and then interpret these ideas in light of prior knowledge, environmental clues, and social context (Valencia & Pearson, 1987; Yore & Shymansky, 1991). Since what students construct determines what they learn, no two students are guaranteed to learn exactly the same thing when reading a science text (Glynn & Muth, 1994). Construction of meaning is a personal, internal, mental process regardless of the information source provided (Farragher & Yore, 1997). Readers, not texts, create meaning as they negotiate with authors.

What the reader brings to the text is a critical variable in the meaning they construct, and this depends heavily on the experiences they have had (Alexander & Kulikowich, 1994; Yore & Shymansky, 1991). The knowledge constructed by children based on direct experience is frequently inconsistent with the ideas of expert scientists, as indicated by the vast literature on misconceptions and alternative frameworks. Yet, these constructions are remarkably consistent, suggesting that they are based on a common body of observations (Linn et al., 1989; Watters & English, 1995). When real-world experiences conflict with formal knowledge, it is often the formal knowledge that suffers

(Alexander & Kulikowich, 1994). One criticism of print-based science instruction is the decoupling of sensory experiences and symbolic labeling (Holliday et al., 1994). Students need to appreciate the connections between the real-world experiences they have had and the formal knowledge they are expected to know, if they are to confront their misconceptions and embrace a "scientifically correct" understanding.

Studies indicate that science teachers recognize the importance of science reading and science reading instruction, and yet few teachers report utilizing activities to improve the cognitive and metacognitive skills of students (DiGisi & Willett, 1995; Yore, 1991). Research suggests that middle-school-aged students do not consistently increase their metacognitive awareness of science reading, science text, and science reading strategies with further schooling as they do with narrative text (Yore et al., 1998). Whether explicitly taught or not, these skills are necessary for successful reading.

Assessments suggest that many students have difficulty reading and comprehending scientific writing. The conceptual density of science text, the prior knowledge demands, the scientific language, the patterns of argumentation, the canons of evidence, warrants, and claims, result in a need for a much more deliberate strategic approach to constructing meaning from science text than from most narrative text (Craig & Yore, 1996; Yore et al., 1998). Students have been shown to have a range of misconceptions about the process of reading science. They believe that science vocabulary is the same as ordinary vocabulary, that one can read science as rapidly as narration, and that all science reading is of the same sort and at the same level. These misconceptions ultimately lead to failure to understand scientific writing and often result in science anxiety and avoidance (Mallow, 1991). Myer (1991) contends that some of the difficulty in reading scientific text is that it is characterized by long noun phrases with many words readable as either adjective or noun. Scientific writing also does not use pronouns or replacement for cohesion, making it hard for a non-specialist to follow. Instead, scientific writing uses repetition as a cohesive device. In this way, the cohesion and the relation between sentences are implicit rather than explicit. To accurately interpret scientific text, readers not only need knowledge of the words and the functions of connectives, but they also need to know lexical relations and the social actions that the text represents. It is argued that scientific texts must be understood as part of the larger processes of argument and alliances within scientific communities (Bazerman, 1988).

If learning from science textbooks is to be meaningful, students need to be aware of the conceptual relations that form the basis of scientific expertise and understanding (Glynn & Muth, 1994; Yore & Shymansky, 1991). Students need to learn to challenge the science text, struggle with it, and make sense of it by integrating the new information with what they already know. Efficient, successful science readers are ones who possess knowledge and control of factors related to science reading and science cognition. They are also aware of science text-related factors, such as what text represents; its purpose, value, and limitations; its structure; and its features (Craig & Yore, 1995; Walpole, 1998). To ensure optimal learning, science textbooks must have consistent, predictable, and familiar structures (Young, 1992).

Science writers need to organize instructional materials in an unambiguous and coherent fashion. Authors can also assist students in their construction of scientifically accurate interpretations by providing more explicitness within the text (Holliday & Braun, 1979; Norris & Phillips, 1994a). Studies in which the text has been revised to make it especially well signaled and more explicit, expressly indicating relationships among ideas, have been successful in increasing student learning (Walpole, 1998). Yet, even the most well-written textbooks will be of little advantage if students do not have the knowledge and skills needed to effectively use the textbooks. Research has shown that teaching students to recognize and utilize the organization and structure of the text increases their reading comprehension (DiGisi & Willett, 1995; Ornstein, 1992; Spiegel & Barufaldi, 1994) and the opportune time for explicit reading instruction is the middle school years (Yore et al., 1998). Students need to learn to read sequentially and to classify information as textbooks do. For, in the words of Carter and Simpson (1978):

> Close examination of reading skills reveals that many are actually inherent in logical thought, and thus represent some of the most fundamental "tools of the trade" for scientists. To the extent that our students are good readers, then, they will have mastered some of the skills necessary for good science. But, . . . the opposite is also true: to the extent that our students become proficient in the processes of science, they will also become better readers (p.19).

<u>Summary</u>

There are four general types of text: exposition, argumentation, narration, and description. Text type has a significant impact upon readers' understanding of text, since each text type places different demands upon readers as they construct meaning. Exposition appears to be more challenging to readers than narration. Reasons may include a lack of experience with exposition, a lack of interest or motivation, and being unaware of the text structure and organization characteristic of expository text.

Science textbooks rely heavily on exposition and argumentation, so many students find it difficult to read and comprehend science text. Science textbooks also have unique organizational features which readers must use to build understanding. Science textbooks have become the embodiment of school science and profoundly affect the learning experience of students. Yet, textbooks have been criticized for their presentation of science. They present science as a collection of factual information and technical terms. As well, most do not adequately incorporate and integrate components of scientific literacy, such as science as a way of thinking, science as a way of investigating, and the interaction of science, technology and society. Reliance upon such textbooks could leave students with an incomplete or inaccurate view of the nature of science, thus limiting scientific literacy. Since science textbooks differ substantially across content domain and program, careful evaluation and selection of science textbooks is crucial.

To be scientifically literate, students must have the ability to read science text, since science reading is an integral part of science education. As well, students will need to read science text to keep abreast with the changing world of science and remain scientifically literate. Reading is an interactive-constructive process. The reader actively constructs meaning by interacting with the text. Both characteristics of the reader, such as knowledge, values, and beliefs, and characteristics of the text, such as structure and purpose, influence the meaning that is created. To assist readers in their construction of scientifically accurate interpretations of texts, writers need to organize the text in a coherent fashion, making the text especially well signaled and explicit. As well, readers need to have the knowledge and skills to recognize and utilize the structure and organization of science text.

The importance of science textbooks within science education should not be overlooked. Science reading is the avenue by which students become, and remain, scientifically literate. Yet, as mentioned earlier, many students have difficulty reading and understanding science text. A reason for this is that students have difficulties in dealing with expository text. Given the unique demands of text types, this study investigates the text types used by two different science programs. More specifically, it examines equivalent physical science topics and life science topics in each program. The purpose of this examination is to determine the relative amounts of each text type used in life science and physical science text.

Meaning

Literal versus Inferential Meaning

One difficulty in discussing literal meaning is that there seems to be little consensus on how to define it. There are at least five different meanings within the cognitive sciences: 1) conventional literality, in which literal usage is contrasted with poetic usage, such as exaggeration; 2) subject-matter literality, in which certain expressions are the usual ones used to talk about a topic; 3) non-metaphorical literality, in which one word or concept is never understood in terms of a second word or concept; 4) truth-condition literality, or language that is capable of being objectively true or false; and 5) context-free literality, in which the literal meaning of an expression is its meaning apart from any context. Some of these definitions of "literal" are closely equivalent (Gibbs et al., 1993). Literal meaning, then, appears to be a complex concept. Kintsch (1994) sees the meaning constructed by the reader as being a two-story structure. The lower story is built from the words the reader recognizes one at a time and links together through very simple inferences. This would be suggestive of literal meaning – information provided explicitly by the words, apart from the reader's knowledge or assumptions about the intended meaning. The second story involves the reader elaborating through additional inferences, drawing on his or her knowledge, and arranging the information hierarchically. This corresponds to determining the inferential meaning.

Attending to the literal meaning is an important part of evaluating the communicative quality of a spoken message. Research indicates that young children, and those who know the intended meaning of a message, will overlook message inadequacies and ambiguities. They focus on whether they can construct an interpretation of the speaker's intended meaning rather than the literal meaning of the message. In this way, they overlook alternative interpretations. The ability to attend to literal meaning, then, is a crucial part of comprehension monitoring and referential communication (Beal & Belgrad, 1990; Bonitatibus, 1988). The ability to attend to literal meaning is especially important in situations where there is a premium in the precise communication of technically complex ideas, such as scientific discourse.

It must be emphasized that the context in which a statement is spoken or written is a vital consideration in determining meaning. It is unlikely that there is any single set of attributes that uniquely defines the literal meaning in the same way in all contexts (Gibbs et al., 1993). Austin (1975) emphasizes this point by referring to speech acts, which include the total situation in which an utterance is made. He notes that the words used are to some extent explained by the context in which they are spoken. For example, the word "real" can have many and diverse meaning in different contexts. Therefore, what is meant "can be decided only by examining the full circumstances in which the words are used" (Austin, 1962, p. 41).

Although some linguistic expressions seem quite literal, others represent intermediate degrees of literality. Norris and Phillips (1994b) define reading as inferring meaning from text, by creating an interpretation through the integration of text information and reader's knowledge. There is often more than one adequate interpretation that can integrate the textual information and the reader's knowledge into a coherent and consistent whole. During the process of reading, the reader uses highly reliable inferences derived from the community of language users, concerning such things as conventional word meanings. As well, the reader makes less reliable inferences about aspects such as the author's purpose. Norris and Phillips propose that the obviousness of meaning be viewed on a continuum, with literal and inferential reading being opposite ends of the continuum. These varying degrees of obviousness would also be indicative of varying degrees of inferential reliability.

The pragmatic meaning of text refers to the meaning in relation to the goals and intentions of the writers and to the context of language use. This can also be referred to as inferential meaning. As with written text, the primary purpose of spoken language is to convey a speaker's meaning to a listener. This intention is often only partially present in the literal meaning and, in cases such as irony, may be almost totally absent. Thus, listeners must rely on other information to determine the speaker's intention (Bonitatibus, 1988). For spoken language, characteristics such as tone of voice, cadence, emphasis, and non-verbal cues, provide this addition information. These features of spoken language are not easily reproducible in written language, however. Features such as punctuation, italics, and word order can be used, but are rather crude devises (Austin, 1975). The reader must infer the pragmatic meaning using the context and print cues of the text to decide on the authors' intentions. A central tenet of pragmatic theories of meaning is that the interpretation of text is only possible by taking into account the context in which statements are made (Norris & Phillips, 1994a). As well, the interpretation of text depends upon all that one believes and understands. This includes understanding the purpose and use of language, which is molded by even more fundamental epistemological beliefs.

An important component of scientific literacy is the continuation of life-long learning. For most, reading scientific text will continue to be the primary source of scientific information and learning after high school graduation. Thus, the interpretation of pragmatic meaning is a crucial skill if readers are to maintain scientifically accurate understandings and beliefs. As well, interpreting pragmatic meaning is a basic part of the critical interpretation of science text. Critical interpretation, also viewed as a goal of scientific literacy, requires the reader to evaluate the believability of the text. The science texts used for life-long learning, such as popular reports of science, are likely to be very different from the science textbooks used in school. While the believability of science textbooks need rarely be questioned, the believability of accounts in popular reports of science must be carefully evaluated. Unless readers can do this, they are unable to think critically and are not scientifically literate.

Meaning in Science

Although the text acts only as a blueprint, it is important that science textbooks provide the print cues needed to assist readers in narrowing their construction to that of the author's intended meaning. An important type of print cue in science text is the use of language that enables talk about science. This extensive vocabulary, which I will refer to as the "metalanguage of science", includes terms such as "law," "cause," "observation," "method," "justification," "evidence," "conclusion," and so on. The metalanguage of science lays a foundation for the critical interpretation of science texts. It highlights the unique characteristics of scientific reasoning. An ability to interpret the metalanguage of science is crucial to understanding science as a way of thinking and to achieving scientific literacy.

The metalanguage of science reveals the structure of scientific text. Scientific knowledge is structured in the sense that its statements do not all have the same scientific status or play the same role in scientific reasoning. The use of metalanguage assists the reader in distinguishing between the various types of statements, resulting in an accurate perception of science. The metalanguage of science also reveals the relationships between these various types of statements. For example, one cannot understand what a cause is without understanding its relation to an effect.

The epistemic status of scientific statements varies depending on which aspect of the scientific enterprise is being addressed. To understand scientific research, readers need to understand how the research was done and what was observed. Scientific research involves raising causal questions, using abduction to make alternative explanations, and imagining conditions that allow the deduction of expected outcomes. When outcomes are gathered, they are compared with expectations and conclusions are drawn concerning the degree of support the correspondence between observations and predictions gives to the initial hypotheses (Gibbs & Lawson, 1992). The metalanguage of science indicates these aspects of scientific research, using words such as "hypothesis," "prediction," "method," "data," "observation," and "discover." One purpose of scientific research is to reveal relationships between variables. The strength of the relationship is implied by the type of scientific statement made. Being able to distinguish between statements indicating only that two things are related rather than that one thing causes another is crucial. Metalanguage, such as "cause" and "affect," assist readers in making this distinction.

Given the importance of reading science text to the development and maintenance of scientific literacy, students' abilities to obtain an accurate interpretation of the intended meaning of the text is important. A study conducted by Norris and Phillips (1994a) examined students' abilities to use the metalanguage of science to infer the scientific role of statements in the chain of reasoning of popular science reports. Their findings indicated that, while students were able to interpret the scientific status of statements taken one at a time, students failed to recognize the implied connections among statements. Students have also been shown to have difficulty using logical connectives like "and" correctly, suggesting that this inability would hinder their ability to infer in science (Daniels, 1996). Since the authors' intentions are conveyed in how statements relate to each other, these difficulties in inferring relations are disturbing. Norris and Phillips (1994a) highlight the need for science textbooks to make the relationships among the parts of the text more apparent. The ability to see connections is fundamental to scientific understanding and science textbooks can play a key role in assisting, or hindering, the development of scientifically accurate views.

It must also be noted that using the metalanguage of science in science text does not necessarily assist students in their development of scientific understanding. Sometimes textbooks use metalanguage in such a careless way that it leads to ambiguity, misinformation, or outright error. Gibbs and Lawson (1992) found that many textbooks have inappropriate definitions for the term "hypotheses." Many textbooks also fail to clearly distinguish between hypotheses and predictions. They leave the reader with the impression that hypotheses are the product of inductive reasoning rather than the creative process of abduction. A number of textbooks also give examples of hypotheses that are clearly predictions, not hypotheses. The term "law" is equated with highly supported theories, despite the fact that theories explain patterns in nature while laws merely state what those patterns are. Finally, similar problems were found for the use of the word "theory." The natural sciences are characterized by theories, which are structures of ideas, confirmed by evidence, that explain a body of observations concerning some aspect of nature (Lerner & Bennetta, 1988). A central theory unifies a science so thoroughly that one cannot understand the science outside of the context of the theory and the predictive powers of the theory direct all scientific research. Yet, research indicates that textbooks sometimes portray theories as simply supported hypotheses or they

> conflate the scientific meaning of theory with one of its extrascientific meanings: a fanciful speculation that need not be taken seriously by anyone who doesn't find it attractive, ... [or] they mash observation, inference and theory together and present scientific information as if it were final, immutable truth that has come out of nowhere (Lerner & Benneta, 1988, p. 40-41).

Such misinterpretations of scientific theory ultimately lead to errors in the presentation of the science as a whole. Recognizing the fundamental role that textbooks play in science education, teachers expect textbooks to present an accurate view of the scientific enterprise.

Recent views concerning the nature of science emphasize that scientific knowledge and understanding are both tentative and inconclusive. Science progresses in the context of history and circumstance, since "[it] is human creativity and imagination that push scientific knowledge along, the direction in which it moves being determined by context" (Stein & McRobbie, 1997, p.620). Studies that have examined students' conceptions of the nature of science, however, have found that these defining ideas related to modern views of science were not evident. The students had not recognized the consensus of scientific observation and the changeability of scientific understandings. This may be a result of textbooks misrepresenting the scientific enterprise and presenting scientific information as immutable truth. Based on Myers analysis, Koulaidis and Tsatsaroni (1996) conclude that textbooks "create a context within which the scientific phenomenon is presented as a fact" (p. 63). Lemke (1990) states that science is usually presented and taught "not as a way of talking about the world, but as the way the world is" (p. 126). It is presented as incontrovertible, objective truth. Lemke, and others, have questioned the moral and epistemological basis of how scientific knowledge is presented to the public and how it is generally taught (Hanrahan, 1997, December). While acknowledging that the content of science textbooks is usually uncontroversial and established knowledge, McGinn and Roth (1999) contend that "even reflective high school students recognize that textbooks present scientific knowledge as unshakable truths" (p. 190). The way students conceptualize science influences the understanding they construct when learning about science (Stein & McRobbie, 1997). Research has found that middle school-aged students perceive what is presented in science text as being the absolute truth, ascribing greater authority to the text than to non-print experiences. An efficient science reader, however, realizes that science text is not an absolute truth, but an interpretation of ideas resulting from the scientific enterprise. The reader "evaluates text for plausibility, completeness, and interconnectedness by verifying the textual message against prior knowledge, evidence, and observed reality and by assessing the logic and plausible reasoning of the text's patterns of argumentation" (Yore et al., 1998, p. 34).

An aspect of determining the meaning of scientific text which students seem to have difficulty with is the evaluation of the degree of certainty of scientific statements. Scientific statements in text are asserted with varying degrees of certainty and, in this sense, scientific knowledge is textured. Even when scientists declare statements to be known with certainty, there is recognition that the statements are fallible. Yet, research using popular reports of science has shown that students hold a certainty bias that skews their interpretations towards being more certain of the truth of statements than were the authors who had written them (Norris & Phillips, 1994a). It appears that students need to familiarize themselves with the nature of science text structure and recognize the role of the reader in evaluating science text. Students also need further development of their views of the nature of science. If, in fact, the way in which scientific information is being presented in textbooks is contributing to the difficulties students have in determining the meaning of scientific text, then improving science textbooks in these regards should greatly improve scientific understanding and literacy.

Summary

When readers construct meaning from text, they must consider both the literal and inferential meaning of the text. The literal meaning is determined by linking the individual words together by very simple inferences. It provides explicit information apart from the reader's knowledge and assumptions about the intended meaning. It is important that a reader or listener attend to the literal meaning, especially for evaluating comprehension and referential communication. The context in which the text is written, however, is also vitally important in determining meaning.

It has been proposed that the explicitness of meaning be viewed as a continuum, with literal and inferential reading being opposite ends of the continuum. Inferential, or pragmatic, meaning refers to the meaning in relation to the goals and intentions of the writer. To determine inferential meaning, the reader must examine the context and print cues of the text and make less reliable inferences than with literal meaning. Reading is itself a process of inferring meaning from text. The ability to read and understand science text is a crucial skill. It is both a goal of scientific literacy and a means by which scientific literacy can be maintained.

Students can be assisted in determining the author's intended meaning of text by the use of print cues. An example is the use of the metalanguage of science, words that enable talk about science. Metalanguage reveals the structure of science text. Even with the use of these print cues, students still have difficulty inferring relationships between statements in science text. Metalanguage also helps the reader develop an accurate view of the nature of science. Unfortunately, some textbooks use metalanguage in a careless way, leading to ambiguity, misinformation, or outright error. This study examines the use of metalanguage in junior high school science textbooks. It also investigates the presentation of the structure of science in these textbooks. More specifically, it examines the type of statements that are used to reveal the structure of science and scientific reasoning.

In determining the meaning of science texts, students must realize that scientific writing is textured in the sense that scientific statements are asserted with varying degrees of certainty. Even when presented with a high degree of certainty, scientific statements are not to be taken as being infallible or immutable truth. Previous research, however, has found that students have a certainty bias when reading scientific texts. Recognizing the significant role that science textbooks play in developing students' views of science, this study rates the extent to which scientific statements are presented as "truth" in junior high science textbooks.

CHAPTER THREE

Design of the Study

A current trend in science education research is textbook evaluation using content analysis. Since a person's or group's beliefs, values, attitudes, and ideas are revealed in their communications, content analysis enables researchers to study human behaviour in an indirect way (Fraenkel & Wallen, 1996). Content analysis is primarily descriptive in nature and is a means of systematizing and quantifying information. Content analysis of science textbooks has been undertaken for various purposes. A search of the ERIC database covering 1985-2000 indicates that during this period there were 161 different studies conducted that involved content analysis of science textbooks. The majority of these studies (83) were focused specifically at the secondary or post-secondary level. Only 16 of the studies were limited specifically to the junior high school level, although some of the studies examined science textbooks representing a range of educational levels. The most common purpose for content analysis was to examine the coverage of a specific science concept within the textbook, as seen in 34 studies. The second most common purpose was to reveal misconceptions or errors found in the science textbooks, as found in 16 studies. Other purposes included an examination of the coverage of environmental or global issues (8 studies); the emphasis on STS themes (6 studies); the presentation made of the history, philosophy, or nature of science (7 studies); the emphasis on aspects of scientific literacy (3 studies); the reading level and cognitive demand of the text (9 studies); racial/gender bias (9 studies); the level and type of questioning (5 studies); the activities and the level to which inquiry is promoted (8 studies); and the use of analogies (2 studies).

There were a small number of studies that examined textual characteristics of science textbooks, as does the present study. Hyland (1999) examined the use of metalanguage as a manifestation of the writer's linguistic and rhetorical presence in college microbiology textbooks. The text organization and structure of elementary science textbooks was investigated by Eichinger and Roth (1991) and Farris et al.(1988). Elementary science textbooks, along with ESL schemes, were also analyzed by van Rooyen (1990) for differences in vocabulary, syntax, speech acts, cohesion, and coherence. At the senior high level, Strube (1988; 1989) examined the language of physics textbooks and Ramasamy (1985, April) analyzed secondary science texts for linguistic content. The only study of textual characteristics focused on the junior high level was conducted by Wignell (1994) and involved the use of systemic functional linguistics to examine the selections and functions of different sets of genres in science and history textbooks. To date, there has not been a content analysis undertaken to examine the specific textual characteristics of junior high science textbooks that the present study examines. No previous study has examined junior high science textbooks in terms of text type, the use of metalanguage, and the presentation of statements in terms of scientific status, role in scientific reasoning, and truth status.

Although specific details of the procedures used in analyzing text content may vary greatly from study to study, two general techniques of content analysis have been widely used. The first technique involves the researchers' application of a classification scheme to the materials to be analyzed with respect to the content of interest (Jeffrey & Roach, 1994). The second technique applies computers in classifying words and phrases from texts of transcripts. This study relies on the first technique, the application of a classification scheme. For each aspect of the text to be examined, a classification scheme was developed and applied to the text. Fraenkel and Wallen (1996) outlined three other common variations in types of content analysis. The first involves an analysis in terms of frequency counts. After the units of coding are identified and the coding categories are defined, a careful count is made of the number of times the units that fit the various categories are found in the text. This study utilized this approach extensively. A second variation is a qualitative or non-frequency analysis. With this approach, an attempt is made only to ascertain whether certain categories of units are or are not present. This approach was used in the present study to examine the presence of metalanguage in the science textbooks. The third variation is a contingency analysis, involving a count of the number of instances in which combinations of two or more categories of units are found in the same communication. This approach was not used in this study.

This chapter outlines the criteria by which the selection of text for analysis was made. First, the selection of a life science and physical science unit for each textbook was made and then a representative sample was chosen from within these units. The chapter also outlines the procedure for evaluating the text for each of the relevant aspects pertaining to the questions that this study attempts to answer. These aspects include the text type, use of metalanguage, and the scientific status, role in scientific reasoning, and truth status of statements within the text. For each of these, a discussion of the evaluation instrument and procedure for analysis are given.

Program Identification

Criteria for Selection

The first criterion used to select the textbook programs this study investigates is the academic level for which the textbooks have been written. This study focuses on junior high school programs for several reasons. First, much of the research on science text to date has focused on high school and university levels (Craig & Yore, 1995). Also, the junior high school years are crucial to the students' development of scientific interest and scientific literacy. It is the age at which students progress towards abstract thinking and begin to establish important conceptual foundations for learning science (Glynn & Takahashi, 1998). Junior high is often the stage at which students lose interest in school, and especially science. Some students, especially females, begin to form the opinion that science is too difficult to pursue. Finally, it is also the last common science curriculum that students have. Upon entering the senior high school program, students vary in their choices of science courses. While some students will choose to maintain a strong science content in their educational program, other students will limit their science studies to that of the minimum requirements for graduation. Unfortunately, still others remove themselves from the educational system entirely and terminate their formal science education altogether. For these students, the foundation for the development of scientific literacy must be firmly established before the completion of junior high school, if these students are to become scientifically literate adults.

Another criterion for selection is the extent to which the textbook programs are used within Canada. The programs that were selected are currently used, or approved for use, in several Canadian provinces. They are the authorized learning resources for the junior high school science program in Newfoundland and Alberta. One of the textbook series, *Science Directions*, is a recommended learning resource for the provinces of Saskatchewan and Manitoba. The other, *SciencePlus Technology and Society*, was specifically developed for the Atlantic Provinces of Canada and for Ontario. Through significant extension and modification, an edition was developed to specifically support the Alberta curriculum. As such, these textbooks are readily available and easily accessible.

Programs Selected

The two programs selected for this study are *Science Directions* (1991) published by John Wiley & Sons/Arnold Publishing, and *SciencePlus Technology and Society* (1989) published by Harcourt Brace Jovanovich. Both of these programs have separate textbooks for each of the junior high school grades (7-9), as well as teacher resources. They are general science textbooks, including content from life science, physical science, and earth science in each year of the program.

Science Directions. The *Science Directions* program was developed specifically for the Alberta junior high school science program, but has been adopted by other provinces, including Newfoundland. In its development, it was reviewed by Alberta Education and each unit was field tested. All the textbooks in the program, from grade 7 to grade 9, have six units. Each unit is designed to develop student's critical thinking abilities and "introduces a major area of science, using an appropriate balance in emphasis: nature of science, science and technology, and science-technology-society (STS)" (*Science Directions*, 1991, p. x). Table 3.1 provides an overview of the units in each grade level.

Each unit includes many and varied activities, followed by three levels of questioning to help students consolidate their findings, to challenge them to reason and reach conclusions, and to encourage investigations or explorations in new directions. *Checkpoint* questions provide review throughout the unit and each unit ends with a unit review. There are also a number of special features in each unit. Brief statements of scientific, technological or societal interest are given under the heading, *Did You Know? Science and Technology in Society* sections highlight real-life applications of the scientific ideas being investigated. There is also a career feature included.

Accompanying each grade-specific textbook is a *Teacher Resource Package*. This provides guidance on the program and general information concerning various teaching strategies. It also provides teachers with specific lesson plans, suggestions for further activities and extensions, and reproducible worksheets that reinforce the ideas being taught. In addition, sample questions are included for the purpose of evaluation.

SciencePlus Technology and Society. *SciencePlus Technology and Society* (1989) was developed by the Atlantic Science Curriculum Project (ASCP). The materials were extensively field tested and benefited from the critical reviews and advice of Canadian scientists and of educators from England and the United States of America. *SciencePlus Technology and Society* uses a directed discovery, or inquiry-based approach, including many activities under the heading, *Explorations*.

Like *Science Directions*, *SciencePlus Technology and Society* has a separate textbook for each of the junior high school grades (7-9), as well as a teacher's resource package. Each textbook contains six units and has content that includes life science, physical science, and earth science topics. Table 3.1 gives a breakdown of the units in each grade level. *SciencePlus Technology and Society* attempts to present science in the context of society, giving particular attention to major science-related social issues.

SciencePlus Technology and Society textbooks also have a number of special features. *Science in Action* sections present conversations with people who use science in their work and provide the students with many project ideas. The *Science on Your Own* feature includes questions and research projects designed to develop a better understanding of the links between science, technology, and society. Each unit ends with a *Brain Teasers* section that reviews the material discussed in the unit. A *Teacher's Resource Book* is also available with this textbook series. It provides unit overviews, sample lesson plans, solutions to textbook questions and reproducible worksheets for the students.

Table 3.1: Comparison of Units in the Junior High Science Programs

	Grade 7		Grade 8		Grade 9	
Unit	***Science Directions***	***Science Plus***	***Science Directions***	***Science Plus***	***Science Directions***	***Science Plus***
1	A Close Look at Life	Living Things	Matter and Mixtures	Interactions	Understanding Chemistry	Diversity of Living Things
2	Structure and Design	Force and Motion	Energy and Machines	Solutions	Fluids and Pressure	Chemical Changes
3	Forces and Motion	Temperature and Heat	Consumer Product Testing	Machines, Work & Energy	Controlling Heat	Heat Travel
4	Temperature and Heat	Structure and Design	The Earth's Crust	Consumer Product Testing	Using Electricity	Fluids
5	Micro-organisms and Food	Changes in the Land	Managing Plant Growth	Face-Lifting a Planet	Diversity of Living Things	Electromagnets
6	Changes on the Earth's Surface	Micro-organisms and Food Supplies	Environmental Interactions	Growing Plants	Environmental Quality	Environmental Quality

Selection within Program

Unit Selection

Criteria. Each grade level of both programs contains six units, as illustrated in Table 3.1. The significant correlation between the programs resulted in comparable units in the two programs. The selection of units to be analyzed began with the elimination of units that are not part of the Newfoundland junior high science curriculum. This eliminated the Grade 7 unit dealing with micro-organisms and food, the Grade 8 unit concerning plant growth, and the Gr. 9 unit discussing fluids (used only superficially in the oceanography unit of the Newfoundland curriculum). Another criterion for selection was the distinction between pure and applied science units. Although this is generally not a clear or sharp distinction, in this context it was considered a safe one to make. For the purposes of this study, a comparison of the text structure of life science and physical science was desired. As such, it was important to be able to categorize the selected units as largely life science or physical science. Some of the units would more accurately be considered applied science, taking students outside the natural sciences altogether and into the social sciences. For the purposes of this study, only units that were natural, pure science units were considered. This eliminated the Gr. 7 unit concerning structure and design, the Gr. 8 unit dealing with consumer product testing, and the Gr. 9 unit discussing environmental quality. Finally, earth science units were eliminated. This resulted in one life science unit and two or three physical science units per grade level. The life science unit was selected for consideration and one physical science unit was randomly selected for consideration from the remaining units in each grade level of both programs.

The decision to focus on life science and physical science content is based upon two considerations. Firstly, there appears to be a significant difference in text type between these two areas of science. Life science topics tend to be more narrative and descriptive than physical science topics, which is why many students opt for such areas of science (Shamos, 1995). Text type has a significant impact on the reader's understanding of the text (Craig & Yore, 1995) and readers tend to have more difficulty understanding expository text than narrative text (Armbruster, 1991). By analyzing both areas of science, I will be able to establish whether the same text type trends are evident in the junior high science programs. Second, I am familiar with content from both of these areas of science. Although my formal training focused in the life science area, the majority of my teaching experience has involved subjects that fall into the area of the physical sciences, including physics and chemistry. I am also familiar with both of the programs being analyzed, since I have used both as resources while teaching junior high science courses.

Units Selected. Table 3.2 displays the accumulated judgments made during unit selection and the units that remain for analysis. The life science unit in each grade level was automatically selected. This included the Gr. 7 unit about the characteristics of living things (Unit 1 in both programs), the Gr. 8 unit concerning environmental interactions (Unit 6 in *Science Directions* and Unit 1 in *SciencePlus Technology and Society*), and the Gr. 9 unit regarding the diversity of living things (Unit 5 in *Science Directions* and Unit 1 in *SciencePlus Technology and Society*). One physical science unit was randomly selected at each grade level from the remaining units. The selected units were the Gr. 7 unit related to temperature and heat (Unit 4 in *Science Directions* and Unit 3 in *SciencePlus Technology and Society*), the Gr. 8 unit discussing machines and energy (Unit 2 in *Science Directions* and Unit 3 in *SciencePlus Technology and Society*), and the Gr. 9 unit dealing with heat transfer (Unit 3 in both programs).

Table 3.2: Selection of Units of the Junior High Science Programs

	Grade 7		Grade 8		Grade 9	
<u>Unit</u>	***Science Directions***	***Science Plus***	***Science Directions***	***Science Plus***	***Science Directions***	***Science Plus***
1	A Close Look at Life ★	Living Things ★	Matter and Mixtures	Interactions ★	Understanding Chemistry	Diversity of Living Things ★
2	[illegible]	Force and Motion	Energy and Machines ★	Solutions	Fluids and Pressure	Chemical Changes
3	Forces and Motion	Temperature and Heat ★	[illegible]	Machines, Work & Energy ★	Controlling Heat ★	Heat Travel ★
4	Temperature and Heat ★	[illegible]	The Earth's Crust	[illegible]	Using Electricity	Fluids
5	Micro-organisms and Food	Changes in the Land	Managing Plant Growth	Face-Lifting a Planet	Diversity of Living Things ★	Electromagnets
6	Changes on the Earth's Surface	Micro-organisms and Food Supplies	Environmental Interactions ★	Growing Plants	[illegible]	[illegible]

Legend:

	Not included in Newfoundland curriculum
	Applied science units
	Earth science units
	Units eligible for selection
★	Units selected

<u>Sample Selection</u>

<u>Criteria</u>. The specific samples to be analyzed were chosen from the selected units in each grade level of the programs. The ideal situation would be to analyze the same topics within these units in each program. However, there are numerous difficulties with this approach. First, it would be very difficult to isolate common topics within the units, because each program varies in how it deals with the general theme of the unit. It would

require considerable subjectivity in deciding what constitutes a particular topic. Second, even when the programs appear to have common topics within the units, the programs cover these topics to varying degrees of depth. Since this study is focused on obtaining an overall picture of what junior high school science textbooks are like, rather than comparing the specific textbook programs, random sections of each unit were selected instead. Any thought of comparing the textbook programs must be rejected. The only valid comparison that can be made is between text of differing branches of science (life and physical).

Random selection is key to ensuring validity and dispelling any impression of bias (Popham, 1993). However, for the purposes of this study, it was also important to preserve significant segments of connected text. Therefore, rather than randomly selecting individual pages of text, a larger block of text was randomly selected and analyzed sequentially. Sequential analysis was used because of the important role contextual clues play in the coding process. As Eltinge and Roberts (1973) point out, the advantages to validity afforded by within-chapter sequential coding can be considered more valuable than any additional benefits that might be gained with a totally random ordering for coding purposes. Therefore, one block of text was randomly selected from each unit. The samples represent 10% of the pages of each selected unit, disregarding end of chapter review sections, rounded upwards to a whole number of pages. Dukes and Kelly (1979) recommend sampling 10% of the text for readability studies. The samples were chosen by randomly selecting the starting page numbers of the blocks of text from a random numbers table. Only those page numbers that allowed a 10% sample of the unit to follow were used. Pages that exclusively contained review questions, pictures, lab activities, vocabulary terms, or objective and goal statements were skipped and not considered part of the sample. Question sections or lab activities embedded in the main text were also ignored.

The pages of the textbooks presented the text in varying fonts, formats, and line lengths. If proportions of the text displaying various characteristics were to be determined, it was necessary to standardize the format of the text. Upon randomly selecting the starting page numbers for the samples and determining the number of pages that represented 10% of the units, the specific page numbers of the samples were determined. Eliminating lab activities, questions, vocabulary lists, goal statements, and review sections, the rest of the text in each sample was re-typed into a continuous block of text with a common font size and format. Indentations were not used to indicate paragraph divisions and single spacing was used to separate both words and sentences. For the purposes of this study, therefore, the operational definition of a *line* is the amount of text that fills a line when typed on a standard page, with 1 ¼ inch margins, using Times New Roman font of size 12.

Samples Selected. Table 3.3 specifies the particular sections of each of the selected units that were selected as samples to be analyzed. It also indicates the text length of the sample after it was placed into a common font and format, to the nearest quarter of a line. The text samples from *Science Directions* are generally longer than the text samples from *SciencePlus Technology and Society*. This reflects the fact that the *Science Directions* textbooks tend to have more text per page and fewer illustrations, activities, and questions integrated into pages that also contain text. The difference in length of the text samples has no effect on the findings of this study, since there is no attempt to compare the two textbook series. Instead, the text samples are combined for each grade and branch of science, rather than being considered separately.

Table 3.3: Sample Sections Analyzed from the Junior High Science Programs

	Grade 7		Grade 8		Grade 9	
Unit	***Science Directions***	***Science Plus***	***Science Directions***	***Science Plus***	***Science Directions***	***Science Plus***
Life Science	Unit 1 pp. 34 – 44 103 ½ lines	Unit 1 pp. 37 – 46 67 lines	Unit 6 Pp. 277 – 283 71 ¾ lines	Unit 1 Pp. 19 – 34 53 ½ lines	Unit 5 pp. 253 – 260 118 ¾ lines	Unit 1 pp. 32 – 46 74 lines
Physical Science	Unit 4 pp. 205 – 215 68 ½ lines	Unit 3 176 – 179 60 lines	Unit 2 pp. 78 – 82 84 ¾ lines	Unit 3 Pp. 169 – 183 44 ¼ lines	Unit 3 pp. 134 – 140 102 ¼ lines	Unit 3 pp. 156 – 161 73 ¼ lines

Text Analysis

Text Type

One of the purposes of this study is to determine the type of text used in junior high school science textbooks. Text type has a significant impact on a student's ability to read and comprehend science text. To determine the text type used, each of the selected samples was analyzed sentence by sentence to determine the text type being used. If the sentence was a presentation or explanation of facts, with the purpose of informing, it was categorized as "exposition." An account of events or a sequence of happenings.

involving the use of characters and time, was categorized as "narration." If the sentence presented the appearance of a person, place, or object, it was categorized as "description." A presentation that attempted to support or test a belief on the basis of reasons was considered "argumentation." The total number of lines of the sample written in each of the different text types was determined, to the nearest quarter of a line. Since there is no attempt to compare the programs, the two samples from a common grade and branch of science were combined and the amount of each text type was determined both as a total number of lines and as a percentage of the whole sample. Then, to better compare the branches of science, all the samples from the same branch of science were combined. The total number of lines of each text type was determined and also expressed as a percentage of the whole sample.

Upon completion of the textbook analysis in terms of text type, I decided to analyze another form of science writing in the same way so a comparison could be made. I wanted the form of science writing to be one that most people would be familiar with and be likely to use. This eliminated journal articles and college level textbooks, because only those pursuing a career or further study directly involving science are likely to make use of these types of science writing. Instead, I decided to use popular reports of science. There are several reasons for this choice. First of all, it is a form of science writing that the average person would encounter in their everyday lives. Thus, it is a familiar form of science writing and one that is most likely to reach a large proportion of the population. Also, upon completion of high school, individuals are expected to remain scientifically literate. This involves keeping abreast of major scientific changes and being able to appreciate their impacts on technology and society. The most likely way that adults will keep up with changing scientific knowledge is through popular reports of science (National Science Board, 1998; Select Committee, 2000).

The popular reports of science analyzed were the same ones as used by Norris and Phillips (1994) in their study. Their study examined the ability of students to interpret pragmatic meaning when reading in popular reports of science. By using the same articles, a comparison of the results and conclusions of both studies can be made. The articles were also selected to ensure the reports were short in length, covered different areas of science, described both applied and basic science issues, and represented a range of scientific technicality. The reports included "Weather Can Make You Sick" (Weinhouse, 1992), "New Animal Species found in Vietnam" (1992), "Breakfast of Champions" (McDowell, 1992), "Inner Glow" (1992), and "Researchers Take Theory on Cow's Milk-Diabetes Link a Step Further" (Taylor, 1992).

The total number of lines in each report written in the different text types was determined, to the nearest quarter of a line. The amount of each text type was determined both as a total number of lines and as a percentage of the whole report. The results of the individual reports were then combined to give an overall view of the proportion of each text type found in popular reports of science.

Truth Status

Statements in scientific text are asserted with varying degrees of certainty and, in this sense, scientific knowledge is textured. There is recognition that even when statements are presented as certain and true, they are still fallible. Truth status refers to the extent to which a statement is presented in the text as being true or false and reflects the amount of certainty the writer has about the scientific information. For example, a statement may be presented as true or only likely to be true.

It has been found that students reading popular reports of science have a certainty bias and tend to read statements as being more "true" than is actually reflected by the truth status of the statements. Textbooks have been criticized for misrepresenting the scientific enterprise and presenting scientific information as immutable truth. If this criticism has merit, the tendency of students to overestimate the truth of scientific statements may be a result of receiving a science education that has trained them to accept scientific information as true. Given the extent to which textbooks influence science education, it is vitally important that scientific statements in textbooks accurately reflect the nature of science and the texture of scientific knowledge. A purpose of this study, then, is to determine the truth status of statements in junior high school science textbooks.

The reported truth status of statements was categorized using a five-point scale, as outlined by Norris, Phillips, and Dawson (1997). The categories were "true," "likely to be true," "uncertain of truth status," "likely to be false," and "false." The statements were extracted from the text such that they were in indicative mood and that modalities and intentionalities were not indicated explicitly. For example, consider the following sentence from the text: "In fact, it may be that all living things have such built-in clocks." Taken in its entirety, it is true that "it may be that all living things have such built-in clocks." The statement that was extracted, however, was "all living things have such built-in clocks." The truth of this statement is more uncertain, as presented.

As the selected text passages were read, it became evident that truth status was not applicable to certain parts of the text. These included directions or instructions given to the student, fictional narratives or examples, and descriptive poetry. Thus, the text samples were shortened to eliminate these parts. The total number of lines of text which fit into each of the established categories was determined and expressed as a percentage of the total text sample analyzed, for each grade and branch of science. An overall summary for life science, physical science, and for the total combined text was also established.

The popular reports of science, previously analyzed in terms of text type and metalanguage, were analyzed in terms of truth status of statements, as well. In this way, the texture of scientific knowledge as presented in the two forms of scientific writing could be compared. The total number of lines of text which fit into each of the established categories was determined and expressed as a percentage of the total text sample analyzed for each individual popular report of science. An overall summary for the total combined text of the popular reports of science was also established.

Metalanguage

There is an extensive vocabulary used in science writing that helps indicate the structure of scientific knowledge. This vocabulary can be referred to as the metalanguage of science. The use of metalanguage is significant because readers can use the metalanguage explicitly provided in the text to assist them in the construction of meaning. The range of metalanguage use also is indicative of the sophistication of the text. A purpose of this study is to determine the frequency with which metalanguage is used in junior high school science textbooks. To determine this, a preliminary list of metalanguage words was constructed. This list included words that are vital to the discussion of science, such as "theory," "law," "observation," "method," etc. Then, through the process of reading the sample sections of the textbooks, this list was expanded to include other words that actively indicate the scientific status and role in scientific reasoning of the text. This final list of metalanguage words is in no way exhaustive, as a list of all possible metalanguage words would be indefinitely long, but it is broadly representative. When a final list was completed, the sample sections were re-read and all the metalanguage words in the list were highlighted in the text. Table 3.4 provides the metalanguage list used in the analysis. Words that are used synonymously have been grouped together for discussion purposes. As well, alternative forms of these words were also highlighted. For example, in addition to the word "inference," any occurrence of the words "infer," "infers," "inferring," or "inferred" would be considered to be equivalent and would also be included.

After highlighting the words listed in the Table 3.4, the frequency of metalanguage use was determined for each grade and branch of science by tallying the number of words highlighted and calculating the frequency per line of text. As well, the number of occurrences of each of the words in the list was also tallied for the entire text analyzed, with synonymous words being grouped together. This was done to illustrate the type of metalanguage most frequently used in junior high school science textbooks.

Table 3.4: Metalanguage List for the Purpose of Analysis

Theory
Hypothesis
Prediction
Inference
Discover
Invent
Conclusion
Justification
Law
Observe, notice, find
Method, procedure
Evidence, data
Test, research, experiment, investigation, study, examination
Cause, effect, influence, result, determine, relate

Upon completion of the analysis of metalanguage use in junior high school science textbooks, it became apparent that a reference base was needed. Otherwise, there is no way of knowing if the amount of metalanguage use found for junior high science textbooks is high or low. Thus, the same popular reports chosen for text type analysis were also used to determine the frequency of metalanguage use in popular reports of science. Norris and Phillip's (1994) study dealt specifically with students' abilities to interpret the scientific status and role in scientific reasoning of statements in popular reports of science, recognizing that metalanguage use assists the students in this endeavour. By using the same articles, a comparison of the results and conclusions of their study and the present one can be made.

Using the metalanguage list given in Table 3.4, the reports were read and the metalanguage words were highlighted. The frequency of metalanguage use was determined for each report by tallying the number of words highlighted and calculating the frequency per line of text. The overall frequency of metalanguage use was also determined by combining the results from all the reports. As well, the number of occurrences of each of the words in the list was also tallied for the entire text analyzed, with synonymous words being grouped together. This was done to illustrate the type of metalanguage most frequently used in popular reports of science.

Scientific Status and Role in Scientific Reasoning

Within science text, statements are used to reveal various aspects of scientific status and play various roles in scientific reasoning. In this sense, scientific knowledge can be viewed as structured. As discussed earlier, the use of metalanguage can assist the reader in determining the structure of knowledge, and thus the author's intended meaning. The reader must have the ability to read science text and, using available print cues such as metalanguage, determine the purpose of a statement in relation to the rest of the text. This study investigates the frequency with which various types of scientific status statements are used and the various roles that statements play in scientific reasoning within junior high school science textbooks.

The categories used to analyze the text in terms of scientific status and role in scientific reasoning were determined through the modification of an instrument developed and used by Norris, Phillips and Dawson (1997). Their scoring guidelines lists five categories of scientific status: 1) that one thing generally causes or influences another; 2) that one thing generally is related to another; 3) what was observed; 4) what prompted the work to be done; and 5) how the research was done. The selected text was read and statements were categorized into these categories. As the text was read, however, an attempt was made to also determine the general types of statements used in the text relative to the categories listed in the scoring guidelines for the role in scientific reasoning. Given that the instrument was developed for use with popular reports of science rather than textbooks, it was found that some of the categories listed were not applicable to the text, while other general categories were missing. Through modification, therefore, the final categories used to determine the role in scientific reasoning of the text were: 1) statement of fact or conclusion; 2) explanation of a phenomena; 3) suppositions for the purpose of exploring possibilities, such as "if-then" statements; 4) reasons provided to support a statement; 5) examples; and 6) comparison/contrast.

As the selected text passages were read, the total number of lines of text which fit into each of the established categories was determined and then expressed as a percentage of the total text sample, for each grade and branch of science. A comparison of the branches of science, across all grades, was also made. It is important to note that a given statement could fit into more than one category. For example, a statement labeled as a "statement of fact or conclusion" could also be labeled as "what was observed." As well, a statement showing "that one thing generally causes or influences another" could be part of an "explanation of a phenomena." Therefore, the percentages listed for each category do not total 100%, but are still indicative of the relative frequency of each of the types of scientific status statements and statements playing various roles in scientific reasoning.

CHAPTER FOUR

Results of Study

Text Type

Tables 4.1, 4.2 and 4.3 provide a breakdown of the text type used in each grade of the junior high school science textbooks that were sampled. There were a number of interesting findings. First of all, there was no evidence of argumentation being used at the junior high school level. The amount of description was also extremely limited, accounting for no more than 4.5 % of any of the samples. It was completely absent from the Grade 8 textbook samples. The two types of text most frequently found in the textbooks were exposition and narration. The vast majority of the text, however, is written as exposition. The amount of exposition ranged from 78.7 % in the Grade 7 life science sample to 100 % in the Grade 8 physical science sample. The amount of narration ranged from 0.0 % in the Grade 8 physical science sample to 24.7 % in the Grade 7 physical science sample.

Table 4.1: Text Type used in Grade Seven Science Textbooks

	Grade 7			
Text Type	**Exposition**	**Narration**	**Description**	**Argumentation**
Life Science	134 ¼ lines 78.7 %	28 ½ lines 16.7 %	7 ¾ lines 4.5 %	0 lines 0.0 %
Physical Science	93 ¾ lines 73.0 %	31 ¾ lines 24.7 %	3 lines 2.3 %	0 lines 0.0 %

Table 4.2: Text Type used in Grade Eight Science Textbooks

	Grade 8			
Text Type	Exposition	Narration	Description	Argumentation
Life Science	122 ¾ lines 98.0 %	2 ½ lines 2.0 %	0 lines 0.0 %	0 lines 0.0 %
Physical Science	129 lines 100.0 %	0 lines 0.0 %	0 lines 0.0 %	0 lines 0.0 %

Table 4.3: Text Type used in Grade Nine Science Textbooks

	Grade 9			
Text Type	Exposition	Narration	Description	Argumentation
Life Science	184 lines 95.5 %	8 ¾ lines 4.5 %	0 lines 0.0 %	0 lines 0.0 %
Physical Science	166 ¾ lines 95.0 %	7 ½ lines 4.3 %	1 ¼ lines 0.7 %	0 lines 0.0 %

Table 4.4: Text Type used in Overall Junior High Science Programs

	Junior High Science			
Text Type	Exposition	Narration	Description	Argumentation
Life Science	441 lines 90.3 %	39 ¾ lines 8.1 %	7 ¾ lines 1.6 %	0 lines 0.0 %
Physical Science	389 ½ lines 90.0 %	39 ¾ lines 9.1 %	4 ¼ lines 1.0 %	0 lines 0.0 %

When the two branches of science are compared, life science and physical science, very little difference in terms of text type is observed. This is illustrated in Table 4.4. The patterns are almost identical, with exposition accounting for approximately 90

% of the text, 8 – 9 % being narrative text, and only 1- 2 % of the text being descriptive. These findings confirm some of the expectations I had based on previous research findings. I expected to find very little argumentative text in either branch of science and the results show it to be completely absent from the samples analyzed. As well, I expected to see some descriptive text in both branches of science. Although less than I had anticipated, descriptive writing is equally represented in the life science and physical science topics. One of my expectations, however, was that physical science topics would be more expository than life science topics, with a greater amount of narration in the life science topics. However, these differences between the two branches of science were not found. Expository writing is almost exclusively used, regardless of the branch of science being presented.

Table 4.5: Text Type used in Popular Reports of Science

Article/ Text Type	Breakfast of Champs	New Animal Species	Inner Glow	Milk – Diabetes Link	Weather Can Make You Sick	Overall
Exposition	19 ¼ lines 88.5 %	25 ½ lines 85.7 %	15 ¼ lines 57.0 %	46 ½ lines 80.2 %	13 ¼ lines 100.0 %	119 ¾ lines 80.1 %
Narration	0 lines 0.0 %	0 lines 0.0 %	0 lines 0.0 %	0 lines 0.0 %	0 lines 0.0 %	0 lines 0.0 %
Description	0 lines 0.0 %	4 ¼ lines 14.3 %	0 lines 0.0 %	0 lines 0.0 %	0 lines 0.0 %	4 ½ lines 2.8 %
Argumentation	2 ½ lines 11.5 %	0 lines 0.0 %	11 ½ lines 43.0 %	11 ½ lines 19.8 %	0 lines 0.0 %	25 ½ lines 17.1 %

Table 4.5 gives a breakdown of types of text used in popular reports of science. It provides a very interesting comparison with the text types used in junior high science

textbooks, as summarized in Table 4.4. The vast majority of both forms of scientific text are written as exposition. For junior high science textbooks, exposition accounts for approximately 90 % of the text. Exposition accounts for approximately 80 % of the text in popular reports of science. Both junior high science textbooks and popular reports of science also have very little descriptive writing, accounting for, on average, less than 3 % of the text. There are differences, however. In junior high science textbooks, 8 – 9 % of the text is written in narrative form, while narration is completely absent from the popular reports of science. Perhaps the most significant difference between the two forms of scientific text, however, is in terms of the amount of argumentation. There is no evidence of argumentative text in the junior high science textbooks. This contrasts with popular reports of science, where the amount of argumentation ranges from 0% - 43 % for the individual reports, giving an overall average of 17 %.

Truth Status

As illustrated in Table 4.6 and Table 4.7, there are no statements in the text samples that fit into the categories "likely to be false" and "false." In fact, very little of the text is presented as anything except "true." This category alone account for 90.0% - 98.9 % of the text sample, depending on grade and branch of science. Overall, physical science text is presented as slightly more "true" (95.0 %) than life science text (92.3 %). I expected to find that more statements fit into the "true" category than any other, but the extent to which this it true is surprising. It is also interesting to note that there are more statements that are "uncertain of truth status" than statements that are "likely to be true." I expected that the categories further away from the "true" category would account for decreasing amounts of the text. This can be partially explained by the fact that many of the statements which fit into the "uncertain of truth status" category were addressing the student personally, without direct knowledge of the student. For example, the following statements were made: "but your family may be able to do something about it," "you might be able to add some insulation to your home," and "you might be wondering why some of the groupings in Linnaeus's classification system have Latin names." Without knowing whom the "you" in each of these statements is referring to the writers cannot be certain of the truth of the statement.

Table 4.6: Truth Status of Statements in Grade 7 and Grade 8 Science Textbooks

Category	**Grade 7**		**Grade 8**	
	Life	**Physical**	**Life**	**Physical**
True	134 ¾ lines 90.4 %	93 lines 98.9 %	101 ¾ lines 90.0 %	103 ¾ lines 95.0 %
Likely to be True	9 lines 6.0 %	1 line 1.1 %	6 ¼ lines 5.5 %	3 ¼ lines 3.0 %
Uncertain of Truth Status	5 ¼ lines 3.5 %	0 lines 0.0 %	5 lines 4.4 %	2 ¼ lines 2.1 %

Table 4.7: Truth Status of Statements in Grade 9 Science Textbooks and in the Overall Junior High Science Programs

Category	Grade 9		Overall		Overall
	Life	Physical	Life	Physical	Combined
True	165 ½ lines 95.3 %	157 ¾ lines 92.9 %	402 lines 92.3 %	354 ½ lines 95.0 %	756 ½ lines 93.5 %
Likely to be True	0 lines 0.0 %	3 ½ lines 2.1 %	15 ¼ lines 3.5 %	7 ¾ lines 2.1 %	23 lines 2.8 %
Uncertain of Truth Status	8 ¼ lines 4.7 %	8 ½ lines 5.0 %	18 ½ lines 4.2 %	10 ¾ lines 2.9 %	29 ¼ lines 3.6 %

Table 4.8: Truth Status of Statements in Popular Reports of Science

Category	Breakfast of Champs	New Animal Species	Inner Glow	Milk – Diabetes Link	Weather Can Make You Sick	Overall
True	13 ¾ lines 63.2 %	27 ½ lines 92.4 %	15 ½ lines 57.9 %	37 ¼ lines 64.2 %	7 ½ lines 56.6 %	101 ½ lines 67.9 %
Likely to be True	1 ½ lines 6.9 %	¼ lines 0.8 %	1 line 3.7 %	1 ¼ lines 2.2 %	4 lines 30.2 %	8 lines 5.4 %
Uncertain of Truth Status	6 ½ lines 29.9 %	2 lines 6.7 %	8 ¾ lines 32.7 %	18 ¾ lines 32.3 %	1 line 7.5 %	37 lines 24.7 %
Likely to be False	0 lines 0.0 %	0 lines 0.0 %	1 ½ lines 5.6 %	¾ lines 1.3 %	¾ lines 5.7 %	3 lines 2.0 %

Table 4.8 provides a summary of the truth status of statements presented in popular reports of science. Similar to junior high science textbooks, as summarized in Table 4.6 and Table 4.7, the majority of statements in popular reports of science are written as being "true." There is a difference in terms of amount, however. All of the text samples in the junior high science textbooks analyzed had a least 90.0 % of the text written as being "true," giving an overall average of 93.5 % for the textbooks. For the popular reports of science, however, the category "true" accounted for between 56.6 % -

92.4% of the text, giving an overall average of 67.9 % for the reports. This is considerably lower than for the junior high science textbooks. Another difference is in terms of the number of categories of truth status utilized. Neither form of scientific writing presented statements as being "false," but the popular reports of science did present a few statements as being "likely to be false." This category was completely absent in the junior high science textbooks. Finally, the category "uncertain of truth status" accounted for approximately 25% of the statements in popular reports of science, but less than 4 % of the statements in the junior high science textbooks. Thus, popular reports of science present a more textured and uncertain view of scientific knowledge than junior high science textbooks do.

Metalanguage

Table 4.9 provides an overview of the findings concerning the frequency with which metalanguage is used in junior high school science textbooks. When samples were analyzed for both branches of science at each grade level, the number of occurrences of metalanguage range from 11 to 23. Because these samples were not all identical in length, the frequency of metalanguage use per line of text was determined. Table 4.9 shows that in both Grade 7 and Grade 8 there was a higher frequency of metalanguage use in the life science topics than the physical science topics. The opposite is true for Grade 9, although the difference is much smaller. Comparing the branches of science, metalanguage is used slightly more frequently in life science topics (0.119/line) than in physical science topics (0.095/line). Grouping all the text together, there are 99 occurrences of metalanguage use in 921 ½ lines of text, which is equivalent to 0.107 occurrences per line. That is, there is approximately one example of metalanguage use in every 10 lines of text.

Table 4.9: Frequency of Metalanguage Use in the Junior High Science Programs

	Grade 7	**Grade 8**	**Grade 9**	**Overall**
Life Science	23 occurrences 0.135 / line	20 occurrences 0.160 / line	15 occurrences 0.078 / line	58 occurrences 0.119 / line
Physical Science	11 occurrences 0.086 / line	14 occurrences 0.109 / line	16 occurrences 0.091 / line	41 occurrences 0.095 / line

In terms of the type of metalanguage found in the textbooks, Table 4.10 provides a count of the number of occurrences in the text of each of the words in the metalanguage list, which was used to analyze the text (Table 3.4). Words that are synonymous have been grouped together. As Table 4.10 illustrates, the most common type of metalanguage used is relational words, words that show the relationship between two things. These words include "cause," "effect," "influence," "result," "determine," and "relate." A very close second are words that describe the process of doing science – "test," "research," "experiment," "investigation," "study," and "examination." The third most common type of metalanguage used, which occurs only half as much as the first two, is observational words, such as "observe," "notice," and "find."

Table 4.10: Type of Metalanguage Used in the Junior High Science Programs

Word(s)	#
Law	0
Theory	2
Hypothesis	0
Prediction	0
Inference	1
Discover	6
Invent	3
Conclusion	2
Justification	0
Observe, notice, find	15
Method, procedure	1
Evidence, data	2
Test, research, experiment, investigation, study, examination	33
Cause, effect, influence, result, determine, relate	35

Prior to conducting this study my expectations were to find the terms "observation" and "method" to be widely used in junior high school science textbooks. As mentioned, observational words were frequently used in the textbooks. However, there was only one use of the term "method." Nonetheless, it should be noted that although the word itself was not used, the actual methods or procedures involved in numerous investigations were discussed. This likely relates to the high frequency of use of words showing the process of doing science, such as "test," "investigation," "research," etc.

The frequency of metalanguage use in popular reports of science is provided in Table 4.11. It offers an interesting comparison to the frequency of metalanguage use in junior high science textbooks, as given in Table 4.9. For the text samples taken from the junior high science programs, the number of occurrences of metalanguage use per line of text ranged from 0.078 to 0.160. The overall average, for all the text samples combined, was a frequency of 0.107 occurrences per line of text. For the popular reports of science, however, the number of occurrences of metalanguage use per line of text ranged from 0.150 to 0.500, giving an overall average of 0.348 occurrences per line of text. In other words, metalanguage use is more than three times higher in popular reports of science than in junior high science textbooks.

Table 4.11: Frequency of Metalanguage Use in the Popular Reports of Science

Article	**Breakfast of Champs**	**New Animal Species**	**Inner Glow**	**Milk – Diabetes Link**	**Weather Can Make You Sick**	**Overall**
Meta-language Use	9 occurrences 0.414/line	5 occurrences 0.168/line	4 occurrences 0.150/line	29 occurrences 0.500/line	5 occurrences 0.377/line	52 occurrences 0.348/line

In terms of the type of metalanguage being used, popular reports of science appear to utilize a more restricted range of metalanguage words, as illustrated by Table 4.12. Of the fourteen categories of metalanguage listed, only 6 categories were found in the popular reports of science. Table 4.10 indicates that junior high science textbooks were found to utilize ten of the fourteen categories. There are a number of similarities, however. For both junior high science textbooks and popular reports of science, the two most common types of metalanguage use are relational words, such as "cause", and words that describe the process of doing science, such as "research" and "experiment." Junior high science textbooks have slightly more relational words than words that describe the process of doing science, while the pattern is reversed for popular reports of science. Together, however, these two categories account for 68% of the metalanguage use in junior high science textbooks and 58% of the metalanguage use in popular reports of science. As well, the third most common category of metalanguage use for both types of science writing is observational words, such as "observe," "notice," and "find." This category accounts for 15% of the metalanguage use in junior high science textbooks and 17% of the metalanguage use in popular reports of science. Finally, the words "method" and "procedure" were absent from popular reports of science, as they were for junior high science textbooks. It is important to note, however, that each of the popular reports did indeed describe the actual procedure that was utilized in the experiment or research. As mentioned earlier, this is likely reflected in the high frequency of occurrence of words that describe the process of doing science, such as "test," "research," and "experiment."

Table 4.12: Type of Metalanguage Used in Popular Reports of Science

Word(s)	#
Law	0
Theory	5
Hypothesis	0
Prediction	0
Inference	0
Discover	4
Invent	0
Conclusion	0
Justification	0
Observe, notice, find	9
Method, procedure	0
Evidence, data	4
Test, research, experiment, investigation, study, examination	17
Cause, effect, influence, result, determine, relate	13

Scientific Status and Role in Scientific Reasoning

Tables 4.13, 4.14 and 4.15 provide the categorization of the statements in the text, in relation to scientific status and role in scientific reasoning, for each grade. Table 4.16 gives an overview for each of the branches of science, as well as for the text considered in its entirety. Some of the statements in the text fit into more than one category. For example, some statements could be classified into one category based on scientific status and another based on its role in scientific reasoning. The first five categories are indicative of the scientific status of statements. The results reveal that much of the text does not fit into any of these categories. When the first five categories are totaled, they account for only 13.9% - 22.2% of the text, depending on the grade and branch of science. In other words, 77.8% - 86.1% of the text does not fit into any of the scientific status categories. The first two categories, which contain statements that reveal relationships, account for 5.6 % - 20.4 % of the text, depending on the grade and branch of science. The next three categories, which are descriptive of the process of scientific research, account for 0.6% - 12 % of the text. Overall, in terms of branch of science, the first two categories account for 9.9 % of life science text and 13.3 % of physical science text. The next three categories account for 8.7 % of life science text and 3.6 % of physical science text. This result indicates that statements that reveal relationships are used slightly more often in physical science text, but the process of scientific research is described more often in life science text.

Table 4.13: Scientific Status and Role in Scientific Reasoning of Statements in Grade 7 Science Textbooks

Category	Life Science	Physical Science
That one thing generally causes or influences another	8 ½ lines 5.0 %	13 ¼ lines 10.3 %
That one thing generally is related to another	1 line 0.6 %	2 lines 1.6 %
What was observed	7 ½ lines 4.4 %	0 lines 0.0 %
What prompted the work to be done	2 ¾ lines 1.6 %	4 lines 3.1 %
How the research was done	10 ¼ lines 6.0 %	7 lines 5.4 %
Statement of fact or conclusion	97 ½ lines 57.2 %	72 ¼ lines 56.2 %
Explanation of a phenomena	15 lines 8.8 %	4 ½ lines 3.5 %
Supposition for the purpose of exploring possibilities	0 lines 0.0 %	2 ¼ lines 1.8 %
Reasons provided to support a statement	1 ¾ lines 1.0 %	1 ½ lines 1.2 %
Examples	10 ¾ lines 6.3 %	12 ¼ lines 9.5 %
Comparison/contrast	15 ¾ lines 9.2 %	4 lines 3.1 %

Table 4.14: Scientific Status and Role in Scientific Reasoning of Statements in Grade 8 Science Textbooks

Category	Life Science	Physical Science
That one thing generally causes or influences another	20 ¼ lines 16.2 %	11 ¾ lines 9.1 %
That one thing generally is related to another	5 ¼ lines 4.2 %	2 ¾ lines 2.1 %
What was observed	2 ¼ lines 1.8 %	1 ¼ lines 1.0 %
What prompted the work to be done	0 lines 0.0 %	2 ¼ lines 1.7 %
How the research was done	0 lines 0.0 %	0 lines 0.0 %
Statement of fact or conclusion	73 ¼ lines 58.5 %	80 ¼ lines 62.2 %
Explanation of a phenomena	4 ¾ lines 3.8 %	6 ¼ lines 4.8 %
Supposition for the purpose of exploring possibilities	8 ½ lines 6.8 %	6 lines 4.7 %
Reasons provided to support a statement	1 line 0.8 %	2 ¾ lines 2.1 %
Examples	26 ¼ lines 21.0 %	20 ½ lines 15.9 %
Comparison/contrast	7 lines 5.6 %	0 lines 0.0 %

Table 4.15: Scientific Status and Role in Scientific Reasoning of Statements in Grade 9 Science Textbooks

Category	Life Science	Physical Science
That one thing generally causes or influences another	1 ¾ lines 0.9 %	21 lines 12.0 %
That one thing generally is related to another	11 ¾ lines 6.1 %	7 lines 4.0 %
What was observed	0 lines 0.0 %	0 lines 0.0 %
What prompted the work to be done	9 lines 4.7 %	1 line 0.6 %
How the research was done	10 ¾ lines 5.6 %	0 lines 0.0 %
Statement of fact or conclusion	98 ¼ lines 51.0 %	134 ½ lines 76.6 %
Explanation of a phenomena	4 ¾ lines 2.5 %	14 ¼ lines 8.1 %
Supposition for the purpose of exploring possibilities	2 ¾ lines 1.4 %	2 ½ lines 1.4 %
Reasons provided to support a statement	8 ½ lines 4.4 %	1 ½ lines 0.9 %
Examples	69 lines 35.8 %	14 lines 8.0 %
Comparison/contrast	3 lines 1.6 %	5 ½ lines 3.1 %

Table 4.16: Scientific Status and Role in Scientific Reasoning of Statements in Overall Junior High Science Textbooks

Category	Life Science	Physical Science	Overall
That one thing generally causes or influences another	30 ½ lines 6.2 %	46 lines 10.6 %	76 ½ lines 8.3 %
That one thing generally is related to another	18 lines 3.7 %	11 ¾ lines 2.7 %	29 ¾ lines 3.2 %
What was observed	9 ¾ lines 2.0 %	1 ¼ lines 0.3 %	11 lines 1.2 %
What prompted the work to be done	11 ¾ lines 2.4 %	7 ¼ lines 1.7 %	19 lines 2.1 %
How the research was done	21 lines 4.3 %	7 lines 1.6 %	28 lines 3.0 %
Statement of fact or conclusion	269 lines 55.1 %	287 lines 66.3 %	556 lines 60.3 %
Explanation of a phenomena	24 ½ lines 5.0 %	25 lines 5.8 %	49 ½ lines 5.4 %
Supposition for the purpose of exploring possibilities	11 ¼ lines 2.3 %	10 ¾ lines 2.5 %	22 lines 2.4 %
Reasons provided to support a statement	11 ¼ lines 2.3 %	5 ¾ lines 1.3 %	17 lines 1.8 %
Examples	106 lines 21.7 %	46 ¾ lines 10.8 %	152 ¾ lines 16.6%
Comparison/contrast	25 ¾ lines 5.3 %	9.5 lines 2.2 %	35 ¼ lines 3.8 %

The last seven categories are indicative of the statements' role in scientific reasoning. The most obvious result is that a large portion of the text is presented as statements of fact or conclusion. This category alone accounts for 51.0 % - 76.6 % of the text, depending on the grade and branch of science. It accounts for more in physical science text (66.3%) than life science text (55.1%). Given that very little of this same text has statements that are descriptive of the process of scientific research (0.6% - 12%), most of these statements of fact or conclusion are presented without insight into their origin. It is also interesting to note some of the common techniques used by textbook writers to aid students in learning the textual information. For instance, comparison/contrast is used for an average of 5.3 % of life science topics and 2.2 % of physical science topics. The most widely used technique is that of providing examples. This accounts for 21.7 % of life science text and 10.8 % of physical science text. This is the most significant difference between the two branches of science, in terms of the role of scientific reasoning.

CHAPTER FIVE

Discussion and Conclusions

As discussed in Chapter Two, scientific literacy has become the overarching goal of science education. It is generally believed that scientific literacy is a necessary condition to functioning effectively as a contributing member of society, given the tremendous rate at which scientific and technological advancements are occurring. An evaluation of scientific findings can influence personal, professional, and public policy decisions (Zimmerman et al., 1998). Thus, the purpose of formal science education is to give the students the skills they need to become and remain scientifically literate.

One of these important skills is the ability to read, understand, and learn from scientific texts. This ability is "a mark of one's independence as a literate person" (Alvermann & Gunthrie, 1993, p.5). During formal science education, most of the scientific information students encounter comes from science textbooks. For many students, the textbook *is* science and, thus, the textbook influences their view of the scientific enterprise. The image of science presented to the student is quite often limited to the facts and concepts included in the textbook. Given the extensive role that science textbooks play within science classrooms, the way in which textbooks are written will have an impact on the ability of formal science education to reach its goal of producing a scientific literate citizenry.

If students are to be lifelong learners, maintaining scientific literacy, they need to know how to learn through interacting with all types of print (Digisi & Willett, 1995;

Yore et al., 1998). Although students will develop scientific literacy to some extent through their interaction with science textbooks, when formal education is completed, a major source of new scientific information is likely to be the media and popular reports of science. Therefore, skill in evaluating new scientific findings, as presented in media reports, can be considered part of the collection of skills necessary to be a scientifically literate citizen (Holliday et al., 1994; Zimmerman et al., 1998). Although the subject matter of science textbooks is often uncontroversial and established knowledge, textbooks must help students develop the skills needed to read and understand frontier science, the subject matter of media reports and popular reports of science, if they are to truly be scientifically literate.

The results of this study will be discussed in light of the ideas presented above. The characteristics of the junior high science textbooks analyzed will be presented and their significance will be discussed. As well, the characteristics of popular reports of science will be presented as a comparison to that of junior high science textbooks. Each research question will be addressed separately and recommendations will be made, based on the findings.

Text Type

The first question that this study addresses is: In junior high school science textbooks, what proportion of physical science and life science topics are written using expository, argumentative, descriptive, and narrative text? It was found that the branch of science analyzed had little impact, as both life science and physical science topics display very similar patterns in terms of text type. There was much greater variation between grade levels, in fact. For example, when both branches of science are combined, 76 % of the text is expository in the grade seven science textbook, but the amount is much higher for grade eight (99 %) and grade nine (95 %) science textbooks. There may be several reasons for this. First, it may simply be a product of the specific topics that are being introduced at each level, since different topics are discussed in each grade. It may also reflect the conscious efforts of the authors to include as much narrative text (20 %) as possible at a crucial transition point in the students' science education. As the students leave elementary school, narrative text is much more familiar to them than expository text. Thus, including more narrative text in the grade seven science textbook should make it easier for the students to read and understand the science textbook.

Overall, the text type of junior high science textbooks was found to be overwhelmingly expository (90 %). A similar pattern was also found with popular reports of science, where approximately 80 % of the text is expository. It is important to note, however, that there is considerable variation within the popular reports of science. The amount of exposition in the reports ranges from 57 % to 100 %. Overall, the results suggest that students are being exposed to large amounts of expository writing in their formal science education. In this way, the junior high science textbooks appear to be successfully preparing students to read popular reports of science, which are also largely expository in nature.

The fact that both forms of scientific writing tend to have large amounts of exposition is significant for two reasons. Firstly, by providing an early introduction to expository writing, science textbooks perform a crucial function. They give students exposure to the text type used in popular reports of science. Upon graduation, the popular media will be the most likely source of scientific information for students. The ability to read expository text, therefore, is a key aspect of developing and maintaining scientific literacy. Secondly, the large amount of exposition in scientific writing is significant since students tend to have greater difficulty reading exposition than narration (Armbruster, 1991). The text structure of exposition differs greatly from that of narration and is generally less familiar to readers. When students are made aware of the text structure, however, they are better able to select relevant information, built internal connections, and learn from the text (Alexander & Kulikowich, 1994; Cook & Mayer, 1988). A familiarity with the structure of science textbooks, then, would increase students' reading comprehension (Jacobs & Paris, 1987; Ornstein, 1992; Young, 1992). Knowledge acquisition depends greatly on the skills and strategies students use to read and comprehend expository text (Spiegel & Barufaldi, 1994). The key is to ensure students are made aware of the unique characteristics of exposition and given the reading strategies to learn from exposition effectively.

The development of reading strategies is crucial to the developing the ability to effectively learn from text. Dole, Duffy, Roehler, and Pearson (1991) and Pressley, Johnson, Symons, McGoldrick, and Kurita (1989) provide some examples of reading strategies that are crucial to the reading process and that respond to instruction: (1)

assessing the importance of text-based information and prior knowledge; (2) generating questions to set purpose; (3) summarizing; (4) inferring meaning; (5) monitoring comprehension; (6) utilizing text structure; (7) reading and reasoning critically; (8) improving memory; (9) self-regulating to fix up comprehension failures; and (10) skimming, elaborating, and sequencing. The problem is that few teachers of science have realized how complex and difficult it is to learn from scientific text. While they recognize the importance of reading as a means of learning science, they fail to utilize specific strategies or incorporate explicit reading comprehension instruction into their science curriculum (Craig & Yore, 1996; Digisi & Willett, 1995). This might explain why Wandersee (1988) found that even university students who excelled in their studies demonstrated a limited repertoire of science reading strategies.

Science reading instruction needs to be an integral component of elementary and secondary science teacher education programs (Yore & Shymansky, 1991). Teachers need to be made aware of research findings concerning the connection between science learning and reading and the importance of incorporating reading instruction into the science curriculum. They also need to be armed with the confidence and skills needed to incorporate explicit reading comprehension instruction into the curriculum. Textbook authors can also assist, by providing information and resources that clarify strategies for reading science text. This is especially true for junior high science textbooks, which are the focus of this study, since research indicates that the middle school years are opportune times for explicit reading comprehension instruction (Yore et al., 1998). This is a time when important conceptual foundations for learning science are established, as children move from being concrete, intuitive thinkers to abstract, reflective thinkers (Glynn & Takahashi, 1998).

An interesting finding of this study is that there is no argumentation present in junior high science textbooks. This is similar to some of the popular reports of science, but vastly different from others. The amount of text using argumentation in the popular reports of science ranged from 0 % to 43 %, with an overall average of 17 % . This finding raises several concerns. The first concern relates to the view of science which textbooks are portraying to students. Although there is a recognition that textbooks usually deal with established knowledge, argumentation is a key part of science. In fact, Kuhn (1993) proposes a characterization of science as argument. Kuhn emphasizes that there is no scientific method capable of detaching science from controversy or argument. Reflecting the social activity of science, she argues that even the "facts" of science become argumentative constructions that must be entered into the arena of public debate. If, in fact, students are not being presented with the argumentative nature of science, they are not being given a true picture of how science is done. This study provides support for the criticism that textbooks define science as a collection of facts, rather than a dynamic process of discovery and theory generation (Gibbs & Lawson, 1992; Jabion, 1992; Musheno & Lawson, 1999).

A second concern is that these textbooks may fail to develop critical skills needed for the students to become scientifically literate adults. If students are not being exposed to argumentative text during their formal science education, they may not develop the skills needed to read and comprehend argumentative text. Yet, argumentative text is a key part of some popular reports of science, which adults rely on to keep abreast of new scientific knowledge. Thus, becoming scientifically literate, and remaining scientifically literate, requires the ability to interpret argumentative text. Norris and Phillips (1994) found that students reading popular reports of science had difficulty identifying statements of justification, evidence, and conclusion. This is not surprising when you consider the fact that these students have had little exposure to argumentative text. Yore et al. (1998) describe an efficient science reader as one who "assess[es] the logic and plausible reasoning of the text's patterns of argumentation" (p. 34). This ability is impossible to learn, or demonstrate, when the junior high science textbooks students are using do not provide exposure to argumentative text.

Science textbook authors need to incorporate argumentative text into science textbooks. They can do this in three ways. Firstly, while presenting the established knowledge of science that is currently found in science textbooks, authors can provide a more explicit view of the social activity that led to its acceptance. As well, authors can include examples from frontier science, which would allow students the opportunity to evaluate the strength of the arguments and reasoning used. Finally, authors can incorporate activities that reflect true scientific inquiry. This would influence the way science is done in the classroom and provide opportunities for students to practice reasoning to conclusions, the essence of argumentation. Science teachers can also make the effort to supplement science textbooks with articles from popular reports of science. Thus, students can be given the opportunity to develop the critical reading skills needed to effectively interpret argumentative text.

Truth Status

Scientific knowledge is textured in the sense that not all of its statements have the same truth status and the statements are asserted with varying degrees of certainty. This study looks at the truth status of statements in junior high science textbooks. The specific question that it addresses is: on a five-point scale, from "false" to "true," what proportion of statements in junior high school science textbooks fall in each category?

In terms of truth status, more than 90 % of the text of junior high science textbooks is presented as being "true." The rest is described as being "likely to be true" or "uncertain." Textbooks have been criticized for their presentation of scientific knowledge. It has been argued that school textbooks, by presenting conclusions without proof, create a context in which scientific phenomena are presented as facts or unshakable truths that are to be accepted without question (Koulaidis & Tsatsaroni, 1996; McGinn & Roth, 1999; Shamos, 1995). This study lends support to this criticism.

Popular reports of science provide a contrast to junior high science textbooks. There was greater variation between the individual reports of science than there was between the individual grade levels or branches of science of the junior high science textbooks. Regardless of grade level or branch of science, the amount of "true" text was consistently more than 90 %, ranging from 90.0 % to 98.9 %. Within popular reports of science, the amount of "true" text ranged from 56.6 % to 92.4 %, giving an overall average of 67.9 %. As well, popular reports of science have a small amount of the text presented as "likely to be true" (5.4 %), but almost 25 % of the text is presented as being "uncertain." There is also a small amount of text that is written as "likely to be false" (2.0 %). In this way, the junior high science textbooks present scientific knowledge as less textured and more "true" than the popular reports of science.

Norris and Phillips (1994) found that when students were asked to judge the truth status of statements in popular reports of science, they overestimated the truth of the statements as reported. They demonstrated an epistemic framework within which scientific knowledge is seen as untextured, or at least less textured than it actually is. Norris and Phillips (1994) contend that

> when science textbooks are examined, it is not surprising that students have acquired the view that science discourse ascribes only truth to statements . . . If textbooks are just stores of facts, then it makes pointless any questioning other than of the accuracy of alleged facts. (p. 959)

This study provides support for the view that students are being trained to view science as truth. Yet, students need to develop the skill of recognizing the texture of scientific knowledge if they are to accurately interpret popular reports of science, which is the most likely way that they will keep informed about scientific developments and issues. If, as adults, students are to make informed decisions about science issues that impact society, they must not accept all scientific writing as being true. Without the ability to interpret the texture of scientific knowledge, they cannot be scientifically literate.

Metalanguage

The third question considered in this study is: In junior high school science textbooks, what is the frequency per line of metalanguage use, including such categories as "observation," "methods," "conclusions," etc. It was found that the frequency of metalanguage use for junior high science textbooks ranged from 0.078 occurrences per line to 0.135 occurrences per line, depending on the grade level and branch of science. The overall average was 0.107 occurrences per line, which is approximately one example of metalanguage use for every ten lines of text. There was slightly more metalanguage use in life science topics (0.119 occurrences/line) than in physical science topics (0.095 occurrences/line).

To provide a comparative base, popular reports of science were also analyzed in terms of metalanguage use. The amount of metalanguage use ranged from 0.150 occurrences per line to 0.500 occurrences per line in the individual reports, giving an overall average of 0.348 occurrences per line. A large part of learning science is learning the language to talk about science, or metalanguage, which lays a foundation for a critical interpretation of science texts. With more than three times as much metalanguage used in popular reports of science than in junior high science textbooks, one wonders how well students are being taught the language of science in their most formative years of science education. It is also interesting to note that the students in Norris and Phillips's (1994) study demonstrated difficulty in interpreting the structure of scientific text despite the fact that the popular reports of science contained more than three times as many metalanguage words as junior high science textbooks. If, indeed, metalanguage assists the reader in identifying the structure of scientific text, than it would be expected that students reading junior high textbooks would be even more unlikely to accurately interpret the scientific status and role in reasoning of statements than that demonstrated with popular reports of science. Given that the students reading the junior high textbooks are younger, and thus likely to be less scientifically literate, greater use of metalanguage as an explicit print cue is needed. Reading instruction that helps students make effective use of metalanguage is also needed.

In addition to the frequency of metalanguage use, it is also interesting to note the type of metalanguage that is used in junior high science textbooks and in popular reports of science. The present study found that the two most common types of metalanguage used are relational words, such as "cause," and words that describe the process of doing science, such as "research" and experiment. Relational words accounts for 35 % of the metalanguage use in the junior high science textbooks and 25 % of the metalanguage use in popular reports of science. Words that describe the process of doing science account for 33 % of the metalanguage use in both junior high science textbooks and popular reports of science. Metalanguage to explicitly identify observational statements is also common in both popular reports of science and in junior high science textbooks. It accounts for 15 % of metalanguage use in junior high science textbooks and 17 % of the metalanguage use in popular reports of science. There are other categories of metalanguage that are rarely used, such as "justification," "conclusion," and "evidence." In the popular reports of science, only 4 of 52 occurrences of metalanguage use fit into these categories, and these were specifically the terms "evidence" or "data." The same pattern can be seen in junior high science textbooks, where only 4 of 100 occurrences of metalanguage use fit into these categories. This suggests that readers are not being given important print cues that could assist them in the identification of these types of statements.

Research has shown that students completing high school have proven to be proficient at identifying observational statements or statements of method, but have difficulty identifying statements of justification, evidence, and conclusion (Norris & Phillips, 1994). The results of this study provide insight into why this is the case. In both junior high science textbooks and popular reports of science, metalanguage to identify observations is commonly used. Although the term "method" is hardly ever used, the actual methods or procedures involved in scientific research are described in junior high science textbooks, and especially in popular reports of science. This is reflected by the large amount of metalanguage in both forms of science writing that describes the process of doing science, such as "test," "research," and "experiment." This suggests that when junior high science textbooks reflect the type of scientific text that students will encounter in reading popular reports of science, the textbooks prepare the students to be successful life-long learners. The types of textual characteristics they have been trained to identify in their formal education are easily identified in other forms of scientific writing, as well.

In contrast, the metalanguage categories of "justification," "evidence," and "conclusion" are rarely used in either junior high science textbooks or popular reports of science. Thus, students are not being given the exposure they need to learn to use these forms of metalanguage effectively to identify the type of statement being read. This suggests that textbooks need to provide a large amount of metalanguage, covering a wide range of metalanguage categories, to ensure students can use metalanguage effectively and identify the structure of the text. Print cues, such as metalanguage use, are especially important at the junior high level where students are still developing their skills in reading scientific texts. Students cannot be expected to recognize the implied connections between statements when they have not even been taught to recognize and distinguish the types of statements that are found in scientific text. It is important that science textbooks make the structure of scientific text as explicit as possible. Only when students are proficient at using metalanguage and identifying statements when they are explicitly marked can they be expected to recognize the connections that are implied among statements. Yet, the ability to see connections is fundamental to scientific understanding. Thus, science education must ensure students have the skills needed to interpret scientific text accurately if they are to be expected to play the role of a scientifically literate citizen.

Scientific Status and Role in Reasoning of Statements

The final question that this study addresses is: In junior high school science textbooks, what proportion of the text reflects various types of scientific status statements and statements playing various roles in scientific reasoning? It was found that the most common type of statement is a statement of fact or conclusion, which accounted for between 51.0 % to 76.6 % of the text, depending on the grade level and branch of science. Overall, an average of 60 % of the text in junior high science textbooks is statements of fact or conclusion. In contrast, less than 5 % of the text is presented as statements that described the motivation or procedure of scientific research. Thus, most of these statements of fact or conclusion are presented without insight into their origin. As mentioned in the discussion of truth status, textbooks have been criticized for presenting conclusions without proof and, thus, creating a context in which scientific knowledge is presented as unshakable truths. These findings provide further support for this criticism, by showing that much of the text of junior high science textbooks do, indeed, present conclusions without proof. It is not surprising, then, that students view scientific knowledge as less textured and more "true" than they should.

In terms of scientific status and role in scientific reasoning, there were some notable differences between the two branches of science analyzed. Firstly, a greater proportion of the physical science topics is presented as statements of fact or conclusion (66 %) than life science topics (55 %). As well, common techniques used to aid students in learning the textual information are more common in life science topics. For example, twice as much of the text is given to providing examples and comparison/contrast in life science topics than in physical science topics. These finding may provide insight into why many students feel that life science topics are easier to learn than physical science topics.

Summary

This study identifies a number of trends in the textual characteristics of junior high school science textbooks. In terms of text type, the textbooks were found to be largely expository, with no evidence of argumentation. The statements in the text are overwhelmingly written as being "true." The junior high science textbooks also reflect a limited range of metalanguage use. It is largely limited to observational words, words that describe the process of doing research, and relational words, such as "cause." The frequency of metalanguage use is only one-third that found in popular reports of science. Finally, in terms of scientific status and role in scientific reasoning, the majority of the text is written as statements of fact or conclusion. There is little discussion of the research behind the facts or conclusions, such as what was observed, what prompted the work to be done, or how the research was done.

The branches of science analyzed are surprisingly similar in terms of text type, truth status, and many aspects of scientific status and role in scientific reasoning. It was found however, that there were some differences. A greater proportion of the physical science text is written as statements of fact or conclusion than life science topics. Life science topics, however, have a slightly higher frequency of metalanguage use and utilize techniques to aid the student, such as providing examples and using comparison/contrast, twice as much as physical science topics.

These trends indicate that junior high science textbooks effectively capture certain aspects of science to the neglect of others. They effectively present the information, or facts, of science and they assist students in the identification of certain types of statements, such as observational and methodological statements. They also expose students to large amounts of expository text, provide students with the opportunity to develop the skills of reading exposition. This is an important skill needed to effectively interpret scientific text of various forms and to ensure students are capable of life-long learning. Junior high science textbooks, however, do not present an accurate view of the texture and structure of scientific knowledge. They fail to portray the argumentative nature of science and the nature of scientific reasoning. They also do not adequately present the social activity of scientific research. If the goal of science education is to promote life-long learning and scientific literacy, some aspects of junior high science textbooks appear to aid this process, while others appear to hinder it.

References

Alexander, P.A., & Kulikowich, J.M. (1994). Learning from physics text: A synthesis of recent research. *Journal of Research in Science Teaching. 31*(9), 895-911.

Alvermann, D.E., & Guthrie, J.T. (1993). Themes and directions of the National Reading Reseach Center. In *Perspectives in reading research* (Vol. 1, pp. 1-17). Atlanta, GA: National Reading Research Center.

Alvermann, D.E., Hynd, C.E., & Qian, G. (1995). Effects of interactive discussion and text type on learning counterintuitive science concepts. *The Journal of Educational Research, 88*(3), 146-154.

Armbruster, B.B. (1991). Framing: A technique for improving learning from science texts. In C.M. Santa & D.E. Alvermann (Eds.), *Science learning: Processes and applications* (pp. 104-113). Newark, DE: International Reading Association.

Austin, J.L. (1962). *Sense and sensibilia*. London: Oxford University Press.

Austin, J.L. (1975). *How to do things with words*. Cambridge, MA: Harvard University Press.

Baker, L. (1991). Metacognition, reading and science education. In C.M. Santa & D.E. Alvermann (Eds.), *Science learning: Processes and applications* (pp. 2-13). Newark, DE: International Reading Association.

Barba, R.H., Pang, V.O., & Santa Cruz, R. (1993). User-friendly text. *Science Teacher, 60*(5), 15-17.

Bazerman, C. (1988). *Shaping written knowledge*. Madison: University of Wisconsin Press.

Beal, C.R., & Belgrad, S.L. (1990). The development of message evaluation skills in young children. *Child Development, 61*, 705-712.

Bernstein, Jeremy. (1984). Science education for the non-scientist. *American Educator, 8*(3), 22-25, 44-46.

Bonitatibus, G. (1988). Comprehension monitoring and the apprehension of literal meaning. *Child Development, 59*, 60-70.

Brewer, W.F. (1980). Literary theory, rhetoric, and stylistics: Implications for psychology. In R.J. Spiro, B.C. Bruce, & W.F. Brewer (Eds.), *Theoretical issues in reading comprehension* (pp. 221-239). Hillsdale, NJ: Erlbaum.

Carter, G.S., & Simpson, R.D. (1978). Science and reading: A basic duo. *The Science Teacher, 45*, 18-21.

Chavkin, L. (1997). Readability and reading ease revisited: State-adopted science textbooks. *The Clearing House, 70*(3), 151-154.

Chiappetta, E.L., Sethna, G.H., & Fillman, D.A. (1991). A method to quantify major themes of scientific literacy in science textbooks. *Journal of Research in Science Teaching, 28*(8), 713-725.

Chiappetta, E.L., Sethna, G.H., & Fillman, D.A. (1993). Do middle school life science textbooks provide a balance of scientific literacy themes? *Journal of Research in Science Teaching, 30*(7), 787-797.

Cook, L.K., & Mayer, R.E. (1988). Teaching readers about the structure of science text. *Journal of Educational Psychology, 80*(4), 448-456.

Council of Ministers of Education Canada. (1997). *Common Framework of Science Learning Outcomes k-12*. URL: http://www.cmec.ca/science/framework.

Craig, M.T., & Yore, L.D. (1995). Middle school students' metacognitive knowledge about science reading and science text: An interview study. *Reading Psychology, 16*, 169-213.

Craig, M.T., & Yore, L.D. (1996). Middle school students' awareness of strategies for resolving comprehension difficulties in science reading. *Journal of Research and Development in Education, 29*(4), 226-238.

Cross, R. (1995). Conceptions of scientific literacy: Reactionaries in ascendency in the state of Victoria. *Research in Science Education, 25*(2), 151-162.

Daniels, D. (1996). A study of science textbook readability. *Australian Science Teachers Journal, 42*(3), 61-64.

DiGisi, L.L., & Willett, J.B. (1995). What high school biology teachers say about their textbook use: A descriptive study. *Journal of Research in Science Teaching, 32*(2), 123-142.

Dole, J.A., Duffy, G.G., Roehler, L.R., & Pearson, P.D. (1991). Moving from the old to the new: Research on reading comprehension instruction. *Review of Education Research, 61*, 239-264.

Dukes, R.J., & Kelly, S.A. (1979). The readability of college astronomy and physics texts. *The Physics Teacher, 17*(1), 168-173.

Eichinger, D., & Roth, K.J. (1991). *Critical analysis of an elementary science curriculum:Bouncing around or connectedness?* (Elementary Subjects Center Series No. 32). East Lansing, MI: Center for the Learning and Teaching of Elementary Subjects. (ERIC Document Reproduction Service No. ED 340 611).

Eisenhart, M., Finkel, E., & Marion, S.F. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal, 33*(2), 261-295.

Eltinge, E.M., & Roberts, C.W. (1993). Linguistic content analysis: A method to measure science as inquiry in textbooks. *Journal of Research in Science Teaching, 30*(1), 65-83.

Farragher, P., & Yore, L.D. (1997). The effects of embedded monitoring and regulating devices on the achievement of high school students learning science from text. *School Science and Mathematics, 97*(2), 87-95.

Farris, P.J., Kissinger, R.W., & Thompson, T.E. (1988). Text organization and structure in science textbooks. *Reading Horizons, 28*(2), 123-130.

Flood, J. (1986). The text, the student and the teacher: Learning from exposition in middle school. *Reading Teacher, 39*, 784-791.

Fraenkel, J.R., & Wallen, N.E. (1996). *How to design and evaluate research in education.* NewYork: McGraw-Hill, Inc.

Garcia, T.D. (1985). *An analysis of earth science textbooks for presentation of aspects of scientific literacy.* Unpublished dissertation, University of Houston.

Gaskins, I.W., Guthrie, J.T., Satlow, E., Ostertag, J., Six, L., Byrne, J., & Connor, B. (1994). Integrating instruction of science, reading, and writing: Goals, teacher development, and assessment. *Journal of Research in Science Teaching, 31*(9), 1039-1056.

Gibbs, A., & Lawson, A. E. (1992). The nature of scientific thinking as reflected by the work of biologists & by science textbooks. *The American Biology Teacher, 54*(3), 137-152.

Gibbs, R.W. Jr., Buchalter, D.L., Moise, J.F., & Farrar, W.T. (1993). Literal meaning and figurative language. *Discourse Processes, 16*, 387-403.

Glynn, S.M., & Muth, D. (1994). Reading and writing to learn science: Achieving scientific literacy. *Journal of Research in Science Teaching, 31*(9), 1057-1073.

Glynn, S.M., & Takahashi, T. (1998). Learning from analogy-enhanced science text. *Journal of Research in Science Teaching, 35*(10), 1129-1149.

Hamm, M., & Adams, D. (1988). How science, technology and society issues are presented in science textbooks. *Educational Research Quarterly, 12*(2), 30-35.

Hanrahan, M. (1997, December). *Science literacy: Demystifying texts in science classrooms.* Paper presented at the Australian Association for Research in Education annual conference, 30 November – 4 December, Brisbane [on-line]. URL: http://www.swin.edu.au/aare/97pap/RUSSA416.htm.

Hanrahan, M. (1999). Rethinking science literacy: Enhancing communication and participation in school science through affirmational dialogue journal writing. *Journal of Research in Science Teaching, 36*(6), 699-717.

Hinman, R. L. (1998). Who is scientifically literate, anyway? *Phi Delta Kappan, 79*(7), 540-544.

Holliday, W.G., & Braun, C. (1979). Readability of Science Materials. *Viewpoints in Teaching and Learning. 55*(1), 55-66.

Holliday, W.G., Yore, L.D., & Alvermann, D.E. (1994). The reading-science learning-writing connection: Breakthroughs, barriers, and promises. *Journal of Research in Science Teaching, 31*(9), 877-893.

Hyland, K. (1999). Talking to students: Metadiscourse in introductory coursebooks. *English for Specific Purposes, 18*(1), 3-26.

Iding, M.K. (1997). How analogies foster learning from science texts. *Instructional Science, 25*(4), 233-253.

Inner glow. (1992, July). *Discover, 13*(7), 17.

Jabion, P.C. (1992). A generic biology textbook review: It is time to stop placing band-aids on our biology curricula. *The American Biology Teacher, 54*(2), 72-74.

Jacobs, J.E., & Paris, S.G. (1987). Children's metacognition about reading: Issues in definition, measurement, and instruction. *Educational Psychologist, 22*, 255-278.

Jeffrey, K.R., & Roach, L.E. (1994). A study of the presence of evolutionary protoconcepts in pre-high school textbooks. *Journal of Research in Science Teaching, 31*(5), 507-518.

Johnson, L.L., & Otto, W. (1982). Effect of alterations in prose style on the readability of college texts. *Journal of Educational Research, 75*(4), 222-229.

Kintgen, E.R. (1988). Literacy literacy. *Visible Language, 1*, 149-168.

Kintsch, W. (1994). The role of knowledge in discourse processing: A construction-integration model. In R.B. Ruddell, M.R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading* (pp. 951-995).

Koulaidis, V., & Tsatsaroni, A. (1996). A pedagogical analysis of science textbooks: How can we proceed? *Research in Science Education, 26*(1), 55-71.

Kuhn, D. (1993). Connecting scientific and informal reasoning. *Merrill-Palmer Quarterly, 39*(1), 74-103.

Kyle, W. (1995). Scientific literacy: Where do we go from here? *Journal of Research in Science Teaching, 32*(10), 1007-1009.

Lee, O. (1997). Scientific literacy for all: What is it, and how can we achieve it? *Journal of Research in Science Teaching, 34*(3), 219-222.

Lemke, J.L. (1990). *Talking Science: Language, learning, and values.* Norwood, NJ: Ablex.

Lerner, L.S., & Bennetta, W.J. (1988). The treatment of theory in textbooks. *The Science Teacher, 55*(4), 37-41.

Linn, M.C., Clement, C., Pulos, S., & Sullivan, P. (1989). Scientific reasoning during adolescence: The influence of instruction in science knowledge and reasoning strategies. *Journal of Research in Science Teaching, 26*(2), 171-187.

Lumpe, A.T., & Beck, J. (1996). A profile of high school biology textbooks using scientific literacy recommendations. *The American Biology Teacher, 58*(3), 147-

153.

Mallow, J.V. (1991). Reading science. *Journal of Reading, 34*(5), 324-338.

Matthews, M.R. (1998). In defense of modest goals when teaching about the nature of science. *Journal of Research in Science Teaching, 35*(2), 161-174.

Mayer, R.E., Steinhoff, K., Bower, G., & Mars, R. (1995). A generative theory of textbook design: Using annotated illustrations to foster meaningful learning of science text. *Educational Technology Research and Development, 43*(1), 31-43.

McDowell, J. (1992, May/June). Breakfast of Champions. *Equinox, 11*(3), 17.

McFadden, C.P., Morrison, E.S., Armour, N., Hammond, A.R., Haysom, J., Moore, A., Nicoll, E.M., Smyth, M.M. (1989). *SciencePlus Technology and Society 7.* Toronto: Harcourt Brace Jovanovich Canada Inc.

McFadden, C.P., Morrison, E.S., Armour, N., Moore, A., Nicoll, E.M., Smyth, M.M. (1989). *SciencePlus Technology and Society 8.* Toronto: Harcourt Brace Jovanovich Canada Inc.

McFadden, C.P., Morrision, E.S., Armour, N., Churcher, E., Haysom, J., & Moore, A. (1989). *SciencePlus Technology and Society 9.* Toronto: Harcourt Brace Jovanovich Canada Inc.

McGinn, M.K., & Roth, W-M. (1999). Preparing students for competent scientific practice: Implications of recent research in science and technology studies. *Educational Researcher, 28*(3), 14-24.

Meyer, L.A., Crummey, L., & Greer, E. (1988). Elementary science textbooks: Their contents, text characteristics, and comprehensibility. *Journal of Research in Science Teaching, 25*(6), 435-463.

Moore, M.D. (1988). *A writer's handbook of current English.* Canada: Gage Educational Publishing Company.

Musheno, B.V., & Lawson, A.E. (1999). Effects of learning cycle and traditional text on comprehension of science concepts by students at differing reasoning levels. *Journal of Research in Science Teaching, 36*(1), 23-37.

Myers, G. (1991). Lexical cohesion and specialized knowledge in science and popular science texts. *Discourse Processes, 14*, 1-26.

National Science Board. (1998). *Science and engineering indicators – 1998* (NSB 98-1). Arlington, VA: National Science Foundation.

New animal species found in Vietnam. (1992, August 6). *The Evening Telegram*, p. 12.

Newmann, F.M. (1991). Linking restructuring to authentic student achievement. *Phi Delta Kappan, 72*, 458-463.

Norris, S.P., & Phillips, L.M. (1994a). Interpreting pragmatic meaning when reading popular reports of science. *Journal of Research in Science Teaching, 31*(9), 947-967.

Norris, S.P., & Phillips, L.M. (1994b). The relevance of a reader's knowledge within a perspectival view of reading. *Journal of Reading Behavior, 26*(4), 391-412.

Norris, S.P. & Phillips, L.M. (2000). *How literacy in its descriptive sense is central to scientific literacy.* Unpublished manuscript, University of Alberta at Edmonton.

Norris, S.P., Phillips, L.M., & Dawson, J.R. (1997). *Scoring guidelines: Pragmatic meanings in popular reports of science.* Unpublished manuscript, Memorial University of Newfoundland at St. John's.

Ornstein, A.C. (1992). The textbook curriculum. *Educational Horizons, 70*(4), 167-169.

Paltridge, B. (1996). Genre, text type, and the language learning classroom. *ELT Journal, 50*(3), 237-243.

Popham, W.J. (1993). *Educational Evaluation.* Boston: Allyn and Bacon.

Pressley, M., Johnson, C.J., Symons, S., McGoldrick, J.A., & Kurita, J.A. (1989). The challenge of classroom strategy. *Elementary School Journal, 90*, 3-22.

Ramasamy, K. (1985, April). *Compatibility of language use across the curriculum in school level textbooks.* Paper presented at the RELC Regional Seminar on Language Across the Curriculum, 22-26 April, Singapore.

Roberts, D.A., Durward, W.C., Grace, E.S., Krupa, G., Krupa, M., Hirsch, A.J., Spalding, D.A.E., Baker, B.J., Wohl, S.M. (1989). *Science Directions 7.* Edmonton: John Wiley & Sons Canada Limited/Arnold Publishing Ltd.

Roberts, D.A., Winter, M.K., Gore, G.R., Grace, E.S., Lang, H.M., MacLean, W. (1991). *Science Directions 8.* Edmonton: John Wiley & Sons Canada Limited/Arnold Publishing Ltd.

Roberts, D.A., Winter, M.K., Bullard, D., Hirsch, A.J., Gore, G.R., Grace, E.S., Emerson, B., McClelland, L.W. (1991). *Science Directions 9*. Edmonton: John Wiley & Sons Canada Limited/Arnold Publishing Ltd.

Rutherford, J., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Scruggs, M.M. (1988). What research says about textbooks. *Science and Children, 25*(4), 24-25.

Segal, G. (1997). Towards a pragmatic science in schools. *Research in Science Teaching, 27*(2), 289-307.

Select Committee on Science and Technology, House of Lords. (2000). *Science and Society* (Session 1999-2000, 3rd Report). London: The Stationary Office.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher, 27*(2), 4-13.

Shamos, M.H. (1995). *The myth of scientific literacy*. New Brunswick, NJ: Rutgers University Press.

Spiegel, G.F. Jr., & Barufaldi, J.P. (1994). The effects of a combination of text structure awareness and graphic postorganizers on recall and retention of science knowledge. *Journal of Research in Science Teaching, 31*(9), 913-932.

Spiro, R.J., & Taylor, B.M. (1987). On investigating children's transition from narrative to expository discourse: The multidimensional nature of psychological text classification. In R.J. Tierney, J. Mitchell, & P. Anders (Eds.), *Understanding readers' understanding* (pp. 143-157). Hillsdale, NJ: Erlbaum.

Staver, J. R., & Bay, M. (1987). Analysis of the project synthesis goal cluster orientation and inquiry emphasis of elementary science textbooks. *Journal of Research in Science Teaching, 24*(7), 629-643.

Stein, S.J., & McRobbie, C.J. (1997). Students' conceptions of science across the years of schooling. *Research in Science Education, 27*(4), 611-628.

Strube, P. (1988). The presentation of energy and fields in physics texts – A case of literary inertia. *Physics Education, 23*(6), 366-371.

Strube, P. (1989). The notion of style in physics textbooks. *Journal of Research in Science Teaching, 26*(4), 291-299.

Sutman, F.X. (1996). Science literacy: A functional definition. *Journal of Research in Science Teaching, 33*(5), 459-460.

Taylor, P. (1992, July 30). Researchers take theory on cow's milk-diabetes link a step farther. *Globe and Mail*, pp. A1, A5.

Vachon, M.K., & Haney, R.E. (1991). A procedure for determining the level of abstraction of science reading material. *Journal of Research in Science Teaching, 28*(4), 343-352.

Valencia, S., & Pearson, P.D. (1987). Reading assessment: Time for a change. *Reading Teacher, 40*, 726-732.

Van Rooyen, R. (1990). *The disparity between English as a subject and English as the medium of learning.* (Report SOLING-20). Pretoria, South Africa: Human Sciences Research Council. (ERIC Document Reproduction Service No. ED 341 074).

Walpole, S. (1998). Changing texts, changing thinking: Comprehension demands of new science textbooks. *The Reading Teacher, 52*(4), 358-369.

Wandersee, J.H. (1988). Ways students read texts. *Journal of Research in Science Teaching, 25*, 69-84.

Watters, J.J., & English, L.D. (1995). Children's application of simultaneous and successive processing in inductive and deductive reasoning problems: Implications for developing scientific reasoning skills. *Journal of Research in Science Teaching, 32*(7), 699-714.

Weinhouse, B. (1992, July). Weather can make you sick. *Redbook*, p. 24.

Wignell, P. (1994). Genre across the curriculum. *Linguistics & Education, 6*(4), 355-372.

Wright, J. C., & Wright, C. S. (1998). A commentary on the profound changes envisioned by the national science standards. *Teachers College Record, 100*(1), 122-143.

Yager, R.E. (1983). The importance of terminology in teaching K-12 science. *Journal of Research in Science Teaching, 20*(6), 577-588.

Yore, L.D. (1991). Secondary science teachers' attitudes toward and beliefs about science reading and science textbooks. *Journal of Research in Science Teaching, 28*(1), 55-72.

Yore, L.D., Craig, M.T., & Maguire, T.O. (1998). Index of science reading awareness: An interactive-constructive model, test verification, and grades 4-8 results. *Journal of Research in Science Teaching, 35*(1), 27-51.

Yore, L.D., & Shymansky, J.A. (1991). Reading in science: Developing an operational conception to guide instruction. *Journal of Science Teacher Education, 2*(2), 29-36.

Young, P. (1992). Reader-friendly science. *Science Scope, 16*(1), 22-24.

Zimmerman, C., Bisanz, G.L., & Bisanz, J. (1998). Everyday scientific literacy: Do students use information about the social context and methods of research to evaluate news briefs about science? *The Alberta Journal of Educational Research, 44*(2), 188-207.