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ABSTRACT

Most secondary science courses in North America are designed to use textbooks as the primary or exclusive source of information about the content or processes of science, and most science teachers focus their instruction on a single text. Although there are many serious issues raised by the overwhelming reliance on text-based teaching/learning in science, the text-based approach is likely to remain a dominant instructional method in most secondary science classes. Furthermore, while a large variety of approaches are possible for teaching with science texts, until very recently, little has generally been done to prepare science teachers regarding effective uses of textbooks and for teaching content reading skills in the science classroom. This study attempted to: (1) describe a desired image for science reading instruction and effective use of science textbooks based on current reading research results; (2) describe the current profile of science reading instruction and use of science textbooks in secondary classrooms; and (3) propose the first steps for planned changes in secondary science reading instruction and uses of science textbooks. (CW)

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Implementing Change in Secondary Science Reading and Textbook Useage:

A Desired Image, A Current Profile, and A Plan for Change

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Introduction

Most secondary science courses in North America are designed around textbooks as the primary or exclusive source of information about the content or processes of science, and most science teachers focus their instruction around a single text (Yager, 1983). Although there are many serious issues raised by the overwhelming reliance on text-based teaching/learning in science, the text-based approach is likely to remain a dominant instructional method in most secondary science classes for the near future. Furthermore, while a large variety of approaches are possible for teaching with science texts, until very recently, little has been done to prepare science teachers regarding effective uses of textbooks and for teaching content reading skills in the science classroom (Farrell & Cirrincione, 1984). Few teachers have the background to teach the specific skills and strategies needed by students to successfully carry out the extensive reading tasks demanded by secondary science courses.

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Secondary science is extremely difficult for many students. A large number become disillisioned with science courses and opt out of senior elective sciences. Others become concerned with their own abilities to learn as a result of relatively poor performances experienced in science. The fact that several major studies in recent years have identified a crisis in science education suggests that present science instruction is not meeting the needs of students and society in a world that has become highly influenced by science and technology (Yager, 1983). Perhaps a sizeable portion of the crisis is related to students' inabilities to effectively read, comprehend, and remember science textual information.

A recent survey of science teachers' attitudes toward and knowledge about science reading indicated that science teachers have more positive attitudes than science teachers in the 1960s but have only intuitive understanding about the science reading process (Denning & Yore, 1987; Yore, 1987). Most secondary science teachers valued science reading as a means of acquiring scientific information and accepted responsibility for science reading instruction. Science teachers generally rejected the simple text-driven or bottom-up model of reading, but lacked knowledge about optional reading models and related reading skills and strategies.

This study attempted: (1) to describe a desired image for science reading instruction and effective use of science textbooks based on current reading research results, (2) to describe the current profile of science reading instruction and use of science textbooks in secondary classrooms, and (3) to propose the first steps for planned changes in secondary science reading instruction and uses of science textbooks. Unlike most early st lies in science reading, which focussed exclusively on the characteristics of the science textbooks, this study considered the multi-dimensional science teaching/learning environment in which textbooks are a single component.

Desired Image of Science Reading and Textbook Useage

Piaget and Vygotsky provided much of the foundation for designing effective instructional strategies. Unfortunately, many educators focus on the differences rather than the similarities between Piaget's and Vygotsky's models (Wertsch, 1979). Piaget's emphasis of experience and internalized restructuring is not contrary to Vygotsky's language (speech) as a tool to complex thinking. The issue is not whether experience is important but rather when or where experience and language occur in the learning sequence. The science teacher must design learning experiences rich in all forms of language, activity, and social interaction that engage learners, provide appropriate experience and encourage learners to predict, verify, organize, and restructure their understanding (Anderson & Smith, 1987). Wood (1980) suggests that effective teaching/learning rests on a close relationship between language and action; neither is adequate by itself. Language must be interwoven with activity, at times language leading activity and at other times activity leading language but always interdependent. Instructional strategies must lure learners into action and to new levels of thinking and understanding.

The ability to effectively balance language and activity in a text-centered course is based on the science teacher's understanding of the nature of science text and the science reading process (Yore, 1986). However, a survey of the literature found little research that directly related to reading science materials (Yore & Shymansky, 1985). Consequently, the image of the desired state of science reading and textbook useage must be constructed by projecting content reading results from other disciplines into the unique mosaic of reading requirements related to scientific text.

Science textual materials generally deal with informing the uninformed, misinformed, and inexperienced (Spiro, 1980). Most science texts are not intended to stand alone or be read in isolation of other experiences. Scientific terminology and prose are labels for and symbolic descriptions of experience. The richness of meaning is stored in the associated experiential background, not the symbolic concept label. Science reading comprehension is dependent on the interaction of prior experience and concept labels. Science language utilizes unique lexicon, semantics, logic, and syntax that influence the comprehension of scientific and technological prose (Eisenberg, 1977). Science lexicon consists of words with unique meanings, Latin and Greek root words, and combining forms not commonly used in daily communications (Piercey, 1976). Science prose is semantically and logically expository, which does not parallel oral conversation or fiction story grammars; is terse and concise; and lacks the degree of redundancy found in most fiction. Scientific expository text structures can be classified as description, collection, compare-contrast, causation or problem-solution (Meyers & Rice, 1984; McGee & Richgels, 1985). Science syntax utilizes frequent referents and unusual grammar, such as passive verbs, embedded sentences, and nominalization. Scientific prose contains chained sentences, with logical connectives to indicate, to coordinate, and to limit relationships of two ideas, propositions, or sentences (Gardner, 1980). Logical sequences of stepwise instructions are found frequently in science text (Pikulski & Jones, 1977). Science textual materials contain a high degree of visual adjuncts such as pictures, diagrams, and graphs, which are an integral part of the communication. Finally, scientific prose has embedded in it unique problems related to mathematical language that has symbols without typical phoneme-grapheme relationships and other than left-right/top-bottom saccadic eye movements (Nolan, 1984).

Several models have been used to help describe the reading process, specifically the text-driven (bottom-up) model, the reader driven (top-down) model and the interactive-constructive model. Critical analysis of the text-driven and reader-driven models of reading produced reasons that questioned both theories (Rystrom, 1977). On the other hand, an interactive-constructive model incorporates both unidirectional models (Rumelhart, 1976). As the reader attempts to comprehend the visual and symbolic message in scientific text, meaning may be absent unless prior knowledge or experience is brought to the task, activated, and monitored. Prior knowledge stimulates uncertainties and predictions that often require extraction of additional information from the text or memory, and this interactive process may result in understanding greater than that accounted for by textual information and prior knowledge. Comprehension depends as much on the reader as it does on the text during the construction of meaning (Rumelhart, 1985). Cognitive

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decoding skills access ideas from print, which then must be interpreted in light of prior knowledge, purpose, and task context to construct or invent meaning; while metacognitive executive functions plan, monitor, facilitate, and guide the effectiveness of these processes.

The interactive-constructive model utilizes schema theory to explain the interplay of prior knowledge and print in reading. Many of the comprehension successes and failures can be explained in terms of schema establishment, schema availability, schema selection, and schema maintenance. Assimilation becomes the bottom-up phase of reading that fills voids in a specific schema. Accommodation occurs after unexpected or discrepant information is encoded into a schema causing disequilibrium. Accommodation results in modifications of the selected schema or in selection of a more appropriate schema (Pearson & Spiro, 1982). The reader must be flexible, engaged and interactive, allowing readily available prior knowledge and skills to mediate the print processing in terms of an identified purpose. As the reading process continues, the purpose may be modified, less-available knowledge will be accessed, and new understanding will be invented by the reader. Often the invention can be enhanced by a post-reading activity guided by the science teacher (Yore, 1984). The post-reading activity should provide a supportive scaffolding that aids the reader in acquiring new levels of organizing, analyzing, synthesizing, verifying, and applying inventions.

Recent research on reading comprehension has focussed on the role of metacognition and cognitive skills in the reading process (Weinstein & Mayer, 1986). Metacognition, the conscious knowledge about and awareness of cognitive states and processes, involves at least two separate components: (1) awareness of skills, strategies, and resources required to accomplish a task, and (2) the conscious application of self-regulatory mechanisms to ensure successful completion of a task (Baker & Brown, 1985). Jacobs and Paris (1987) cautiously decomposed metacognitive into two broad categories regarding cognition: self-appraisal and self-management. Each of these categories is further decomposed into three sub-categories. Self-appraisal involves declarative knowledge dealing with propositional understandings, procedural knowledge dealing with awareness of cognitive processes, and conditional knowledge dealing with factors influencing learning. Self-management refers to translating knowledge into action, specifically strategic planning (goal setting, selecting means to achieve goal), evaluating (comprehension or understanding), and regulation (monitoring progress, revising or modifying plans).

One major global metacognitive component of reading is called comprehension monitoring. Comprehension monitoring involves: (1) checking the ongoing comprehension progress of the reading, (2) being aware of discrepancies between the perceived meaning of the text and meanings that are plausible, logical or consistent with the reader's personal knowledge or schema, (3) choosing strategies when necessary to review or re-interpret the text information to find a better fit, (4) evaluating the success of the compensation strategy, and (5) ensuring that comprehension continues to be successful. Compehension monitoring then is a form of thinking about the reading process and related understandings, an executive process that allows the reader to select appropriate skills, detect comprehension failures, make decisions, and apply effective cognitive strategies in a problem-solving approach to overcome the difficulties encountered during the reading process.

Successful, efficient comprehension monitoring is one aspect of metacognition involved in the reading processes of good readers and lacking among poor readers. Research has shown that beginning readers lack many skills associated with effective application of metacognitive strategies (Baker & Brown, 1985), that many aspects of metacognition are developed late in the education of students (Forrest-Pressley & Waller, 1984), and that metacognition is related to achievement (Jacobs & Paris, 1987). Furthermore, poor readers lack attention to selecting and directing skills, text structure knowledge, and even a rudimentary assessment of their own abilities as learners (Alvermann, 1984).

Researchers feel that most secondary and beginning university students would benefit from instruction in aspects of cognitive reading skills, reading metacognition and study of expository text materials (Elshout-Mohr, Van Daalen-Kapteijns & Sprangers, 1988). Some successful metacognition improvement has been reported, but it generally is a lengthy process and may be discounted by what happens outside the intervention (Paris & Jacobs, 1984;). Cross and Paris (1987), Garner (1987), and Pearson and Dole (1987) have outlined critical attributes of metacognitive instruction. They found that effective instruction contained: (1) modelling of the critical task (skill or strategy), (2) guided practice of the critical task, (3) consolidation of the critical task regarding how and when to utilize it, (4) independent practice of the critical task in a controlled situation like a worksheet, and (5) application of the critical task to a normal learning situation. The

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instructional sequence must move the ownership of the critical task from the teacher to the student.

An analysis of reading has identified several specific cognitive science reading skills and strategies over and above those currently associated with developmental reading. The science reading skills cluster around three strands dealing with vocabulary, comprehension, and study skills (Yore, 1984). The vocabulary strand involves: defining and using general and technical vocabulary; using affixes, roots, and combining forms to define words; using context clues to determine the meaning of a word; categorizing words into larger, more easily understood groups; and realizing how analogies and metaphors use relationships to show meaning. The comprehension strand involves literal, inferential, and applied comprehension. Literal comprehension stresses the skills of recognizing main ideas and supporting details; sequencing events and following directions; and using charts, graphs, diagrams, pictures, and equations for better comprehension of the written material and relationship amongst ideas. Inferential comprehension stresses the skills of discriminating fact from opinion, generating summary statements and decisions from evidence, inferring causal relationships, and implying similarities and differences by comparing and contrasting. Applied comprehension stresses understanding at a level in which it can be used to complete an application task. The study skills strand involves facility and efficiency in organizing and making notes; diagramming for better explanation; scanning for specific information; recognizing and using the organization of the textbook and the structure of the written prose (descriptions, collection,

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compare-contrast, cause-effect and problem-solution); and using a general reading plan that surveys, questions, reads, and reviews.

Science reading involves the complex interplay between the text and cognitive reading skills, problem-solving strategies, and executive functions utilized by the reader. A complete understanding of all aspects of reading is far from realized, and a clear differentiation of metacognitive strategies from the cognitive aspects of reading is probably not possible (Champagne, 1987). Self-confidence, sense of purpose, self-awareness, and subject awareness are important affective attributes that also contribute to cognitive/metacognitive processes involved in successful reading comprehension.

A review of the reading literature yields a very positive outlook toward improving science learning through instruction focused on the cognitive and metacognitive aspects of reading, and through the adoption of sequential teaching strategies consistent with a perspective that recognizes the importance of concrete experience, cognition, metacognition, and interactive-constructive nature in successful reading. Efficient reading is a basic learning skill that grows slowly in response to the education and cognitive growth of the student. A distillation of the literature led to the development of a series of science reading objectives that students should have sufficient opportunities to develop and practice during the progress of their secondary science courses. The desired image of an efficient, successful reader of science text materials should be a person who is able to:

1. realize that words are labels for ideas, ideas are based on

experiences, and text is stored descriptions of ideas (experience); that readers must evaluate the textual material; and that readers determine their own purposes for carrying out the reading.

2. develop a sense of the motivation and value for the reading and feel confident that the reading will help them to understand, reinforce, and enrich personal experiences, interests, and needs, and to solve problems.
3. select reading strategies appropriate to the needs of the reading process, for example, when the purpose of the reading is to obtain an overview of the text, the student uses skimming, key words, titles and headings, and first sentences in paragraphs to retrieve the main ideas.
4. realize that the text is not an absolute truth and that all science writing is a form of interpretation and, at least to some extent, all science writing may be a distortion or simplification of information and ideas that have been developed or recorded through the processes of science.
5. have self-confidence in their reading abilities and realize that a comprehension problem may result from poorly written text or abstract ideas, and not just a personal comprehension block.
6. enjoy science reading and are likely to read science materials outside the prescribed text, and they pursue personal interests in science topics through science reading materials.
7. assess their own personal skills as learners and choose strategies for reading the text that fit their self-assessment and avoid reading difficult information without access to prior declarative

knowledge (critical vocabulary and key background concepts) or prior procedural knowledge (plans to review and re-process difficult ideas or concepts).

8. use visual adjuncts in texts, such as graphs, charts, and photographic reproductions, to help clarify, organize, reinforce, enrich or verify the meanings they derive from the text.
9. use efficient vocabulary development skills to determine the meaning of words from context, to dissect words into prefixes, suffixes and root-words, to utilize classification, concept maps, metaphors and analogues to show relationships of key words, and to use mnemonic aids to help remember key words.
10. identify main ideas in a text, delineate supporting ideas and rephrase ideas to show logical connections and hierarchical relationships explicit or implicit in the text.
11. summarize text passages using the following macrorules: delete redundancies, delete trivia, provide superordinates, or select topic sentences, or invent topic sentences when missing.
12. evaluate text passages for plausibility, completeness, and interconnectedness by using their available knowledge to correct mistakes in science text writing or to fill in missing information necessary to make the text plausible.
13. ask themselves questions about the readings that require comprehension and reflect the purpose(s) for reading the textual material.
14. use inferential and applied comprehension skills to critically synthesize, analyze, evaluate and apply information regarding fact

and opinion, bias, generalizations, causal relationships, and distinctions.

15. utilize efficient search-ahead procedures that allow them to construct meaning from related or linked information in other parts of the sentence or paragraph.
16. identify a variety of text structures including description, simple listing, chronological ordering, compare-contrast, cause-effect, and problem-solution and select reading strategies appropriate to the text structures they encounter.
17. monitor their own successes at understanding the reading information as the reading progresses that detects discrepancies in light of the established purpose and consciously adopt or determine strategies to review the text information, which help create a better fit between their schema and the perceived meaning of the text, carry out these strategies, and re-assess the goodness-of-fit for the reviewed textual information and their understandings.
18. adjust their comprehension monitoring to more conscious levels when demands of the reading increase, when difficulties are perceived, and when comprehension is blocked.
19. choose appropriate study skills when there is a need to remember detailed information from text, such as summarizing, outlining, peer testing, and reciprocal teaching.
20. create organized mental images of information in order to help fit the information into existing schema and to help encode the information into long term memory.

Current Profile of Science Reading Instruction and Textbook Useage

In an attempt to assess the present status of science reading instruction and textbook useage by secondary science teachers, 428 secondary science teachers in British Columbia, Canada, were surveyed. Completed Science and Reading Questionnaires were returned by 215 teachers (Yore, 1987). The questionnaire explored the attitudes toward and knowledge about science reading and science reading instruction. Fifteen respondents from a pool of 98 volunteers were also interviewed and their science teaching was observed. The interviews were divided into pre-observation and post-observation structured protocols. The pre-observation interview attempted to clarify the respondents' views about reading models, reading skills, reading instruction, and textbook useages reported on the questionnaire. The post-observation interviews clarified classroom observations and verified interpretations. The interview-observation-interview phase of the data collection was normally conducted during a single school day over a three- to five-hour period. The data reported here relate exclusively to what teachers believed to be important purposes of text and text features, what they did to improve science reading skills and comprehension, and how they used science textbooks in secondary science classes.

Importance and Purpose of Science Reading. Questionnaire data indicated that 90.2% of the respondents believed that reading was an important process in learning science, but a similar percentage believed that all required knowledge about a science concept would not be contained in the science text. A less dramatic response pattern supports the idea that prior science experience was required for science reading to be more than rote memorization. But, most respondents were neutral toward the idea that readers interacted with text to invent meaning (interactive-constructive model). The questionnaires revealed a distinct split on whether or not science teachers' primary responsibility was to impart subject matter knowledge.

The interviews revealed a spectrum of attitudes toward the importance of reading. Most teachers interviewed felt science reading to be very important to students; the majority of these framed their responses around the need for academic students to apply science reading skills in future science studies involving textbooks. They viewed science reading as a key to academic success. Several teachers looked beyond school, viewing science reading skills as essential life-skills, important for survival or success in a technology-oriented society. On the other hand, three teachers viewed science reading as less valuable to students in their lives beyond schools. For them, science reading is losing importance in the information age, as television and other media increasingly control more of people's limited attention. They apparently saw little transfer between reading comprehension and other information processing situations.

Teachers' emphasis within the science classroom did not necessarily reflect their self reported attitudes toward the importance of science reading. Although science reading was considered very important by many teachers interviewed, none felt they placed sufficient emphasis on teaching content reading skills. Several teachers who considered science reading to be very important gave no reading instruction and/or conducted no assessments of reading skills. Observational data on classroom practice support this self-report. Teachers usually assess students' reading abilities in relation to their performances on science content achievement tests. Direct reading skills assessment with specific inventories or instruments seems to be very rare.

Teachers showed only very rudimentary conceptualizations of the causes of reading problems and comprehension failures. For one-third of the interviewed teachers, comprehension problems are strictly the consequence of lack of effort and laziness. Two other teachers felt that poor comprehenders do not expect to understand the text, implying motivational causes for comprehension blocks. Ironically, these same two teachers claimed that existing external sources of motivation are sufficient reason to promote learning from science texts. Three teachers felt that they did not know, or were not lified to say, what causes comprehension blocks in science reading. Only two teachers felt that the expository writing in the textbook may contribute to comprehension problems. Another teacher attributed comprehension problems to poor reading skills, but could not identify the particular skills felt to be deficient. In general, teachers did not recognize the specific causes of comprehension difficulties in science reading and they did not demonstrate any behavioral responsibility for considering these factors as significant foci for instructional strategies, even though they were likely to consider reading to be very important to successful science learning and tacitly accept the responsibility in the abstract.

An important observation about teachers' attitude toward reading skills is that a majority of teachers in this study felt that text material can be learned by all students in their classes, but that some students will require more time. The term, *slow reader* reflects teachers' views of the reader as learner. Few teachers acknowledge that cognitive reading skills necessary for comprehending science text may be poorly developed or lacking in students, or that students lack metacognitive strategies. Furthermore, those teachers who do acknowledge poor comprehenders' deficiencies in reading skills are unlikely to have detailed, informed opinion about the specific nature of reading deficiences.

The interviews revealed that many teachers are actively questioning their basis for text useage in science classes. When presented with a list of three statements corresponding to the three models of the reading process, teachers often had difficulty choosing one model reflecting their beliefs and practices. Several teachers seemed to be in transition from one way of viewing the science reading process toward an attitude more aligned with the interactive-constructive model of the reading process. One teacher's comment illustrates the pattern:

> It's interesting because I work on one assumption, but I think I believe something else. In terms of the way I work, I think the [reader driven model] is the one that I operate on. But in terms of what actually happens, I believe that it is probably an [interactive-constructive process].

Important Text Features. Respondents were asked to rate the importance of specific text features as a means to improve comprehension according to a scale of very important, moderately important, or not important. They were also asked to identify additional features they felt important or unimportant. A majority of science teachers responding identified the use of familiar examples, logical sequencing of concepts, use of numerous visual adjuncts, and use of enthusiastic tone as factors they believed to be very important in increased comprehensibility of science text. Lowering reader anxiety and avoiding extraneous detail were viewed as important or very important by a majority of the responding science teachers. Narrative writing style; limiting technical vocabulary; less concept loading; color, heading and print size; and study questions at the beginning of the passage were identified as being moderately important by the majority of respondents. Science teachers volunteered the following factors as important for increasing comprehensibility of textbooks (number of respondents identifying specific factors in brackets): chapter summaries or reviews (16); good glossary (12); questions at the end of passage or section (12); questions asked at different levels to challenge higher order thinking skills (10); underlining, highlighting, or bold print for key concepts or terms (9); examples that are relevant to the lives of students (8); examples of solved and unsolved problems (7); exercise questions throughout chapter (7); and learning objectives stated in chapter introductions (5). Other factors identified by less than five science teachers were uncluttered page layout, linkage between concepts, index, vocabulary lists, chapter overviews, repetition of key concepts, precise language, anecdotal margin comments, and definitions. The rating of stated features and the identified features appear to support the inferences that science teachers view reading as more than decoding print, scientific prose as unique, and processing aids should be

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included in science textbooks. The lack of tightly clustered responses appears to suggest that practicing science teachers do not have well-defined conceptions of these issues.

The interviews confirmed that teachers do not have consistent expectations from texts. However, a majority of the interviewed teachers identified one or two of the following issues as major expectations of science texts: texts should have information that relates to concrete experiences of the students' lives and texts should provide logical progressions to build higher order thinking and problem-solving skills. Some teachers felt strongly about the need for learning objectives at the beginning of chapters as advance organizers to establish purpose, whereas others emphasized the value of chapter summaries to encourage regular review. Several teachers emphasized the value of visual and graphic components of the text but there were widely varying preferences as to what constitutes appropriate visual design or graphic adjuncts. Cartoons, margin notes, enrichment features, and detailed illustrations had both proponents and opponents in this selection of teachers. Teachers did not refer to published literature or to university coursework as factors influencing their opinions, but some teachers referred to an intuitive understanding of the text features that improves students' understanding.

Effectiveness of Science Reading. The results in Table 1 indicate that science teachers' global assessment of specific teaching/learning strategies. Respondents were asked to rate clusters of specified teaching/learning strategies. The collective opinion was divergent and no single strategy was identified as the most effective approach. The inclusion of common reference activities in each of the three rankings allows a composite rank order of teaching/learning activities to be produced. The thirteen activities ranked from most effective to least effective, as judged by science teachers, were:

Demonstrations

Structured Laboratories

Lectures

Class Discussions, Field Studies, Case Studies

Reading

Media

Models

Computers

Games and Simulations, Debates and Role Plays, Unstructured Inquiry

Provincial assessments indicate that secondary science teachers increasingly rely on textbooks as a supplemental source of information and problems and decreasingly rely on library research (Taylor, Hunt, Sheppy & Stronck, 1982). Thirty-eight percent of the responding teachers indicated they utilized reading from science textbooks half or more of the time, 75% utilized answering questions from worksheets or textbooks half or more of the time, while only 2% utilized library research half or more of the time (Taylor, et al, 1982). Furthermore, teachers reported relying on lectures, discussions, and structured experiments. A more recent provincial science assessment reported similar classroom useage of reading and a perceived increased importance of textbook reading in a new grade 10 science curriculum (Bateson,

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Anderson, Dale, McConnell & Rutherford, 1986).

Insert Table 1 about here

The interviews and observations indicate that teachers rely on a limited number of teaching strategies, specifically, lectures, structured laboratories, teacher-led discussions and reading/question assignments. Frequently, laboratories were verification of lectures and the lessons developed deductively. These strategies correspond to the five activities ranked highest on the questionnaire. According to interview/observation data, teachers use strategies in the following rank order of frequency: teacher-led class discussion, lecture, reading, structured laboratory, and demonstration. Although the study did not involve observations over sufficiently long time periods to make firm conclusions, it appeared to indicate that secondary science teachers tend to under-utilize the strategies they consider to be most effective for teaching science (demonstrations and structured laboratories) and overall, they tend to infrequently or never utilize strategies they rank below reading in terms of science teaching effectiveness (media, models, computers, games and simulations, debates and role plays, and unstructured inquiry).

The interviews revealed that many teachers consider reading to be an essential element of learning in their classes. One chemistry teacher's comment typified the attitude of about one-third of the interviewed teachers: "Students should be reading every day, for every lecture. I assign problems that will require them to read [the text]."

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A large majority of the teachers interviewed used questions from the textbook to create a focus and a need for text readings. Most felt that question assignments are the only reliable method to motivate students to read the text. A number of teachers considered reading to be ineffective in science learning. These teachers have low expectations about students and they report that reading assignments, when given, are usually not carried out by their students. Their strategies usually involve substituting lecture and note-taking or board-copying as more effective alternative information accessing. None of the interviewed teachers felt that reading could form a basis for all or most of the science learning in their courses.

Use of Textbooks. Data in Table 2 indicate science teachers' preferences related to the position within a lesson of four popular teaching/learning activities. The data clearly suggest that Lecture-Demonstration is an activity frequently used to introduce science lessons, while reading textbooks is an activity frequently used late in a lesson.

Insert Table 2 about here

Analysis of the individual activity sequences (permutations) indicated by the respondents revealed that the most common instruction sequences were: Lecture-Demonstration, Laboratory Activity, Class Discussion, Reading (11.6%); Class Discussion, Laboratory Activity, Lecture-Demonstration, Reading (8.8%); and Laboratory Activity, Class Discussion, Lecture-Demonstration, Reading (7.4%). Such instructional sequences appear to indicate that science teachers intuitively try to provide concrete experiences that establish and access prior knowledge and establish a purpose for reading activities prior to actually reading textbooks. Further, the common sequences appear to support the inference that science teachers normally use reading activities to reinforce and enrich concept development rather than to initiate concept formation. Only 13.0% of respondents report using reading as initiating a learning sequence, while 39.5% of respondents report using reading as the final step in a learning sequence. Many respondents cautioned that the activity sequence depended on the concept and learners involved.

The interviews and classroom observations indicated that teachers frequently substituted lectures and copying notes from the chalkboard for text readings. It is not possible to determine whether these alternate information dissemination strategies were more effective than reading science textbooks, but many teachers believed these alternatives were the only effective way to teach. Little evidence of laboratory experiences being used to establish prior knowledge before reading were found.

The three interviewed teachers who preferred a bottom-up (text-driven) model of the reading process placed most emphasis on text processing as the source of learning. They preferred to place reading near the beginning of an instructional sequence. One teacher reported frequently starting an instructional sequence with a reading, another teacher reported providing students with an opportunity to pre-read the text, and yet another teacher reported always providing a lecture introduction followed by a text reading. These teachers felt that students should be able to learn from a text that is well written, even when they are totally unfamiliar with the text topic.

The five teachers who preferred a top-down (reader-driven) model of the reading process were likely to put more emphasis on teaching strategies and the information they present in class, rather than on the text as a source of knowledge. According to the views of these teachers, students must have familiarity with the topic in order for the reading to be more than an exercise in rote memorization. The text may be considered to help students learn science, but for these teachers, providing the right amount of background to prepare the students for the reading was essential. Some teachers felt that many students could learn the course material without reading the text at all. These teachers all placed reading after lecture or discussion in a teaching sequence. Often, they reported providing a laboratory experience or demonstration as a preliminary experience before the reading to access or establish prior knowledge. However, the background knowledge that these teachers provided for students was frequently, if not usually, in an abstract form involving lecture, handouts, notecopying or other passive source, not contrete experience as reported.

The six interviewed teachers with distinct preferences for an interactive-constructive model of the reading process all placed reading as a third or fourth activity in a teaching sequence involving four activities. The observations and interviews of these teachers revealed that they tend to place considerable emphasis on certain pre-reading strategies designed to make the text readings more successful. Two of the teachers stressed the need to develop motivation through pre-reading strategies. One of these teachers used science history and vignettes of historically important science personalities as motivational preliminaries. Two of these teachers did conscious assessments of all reading passages and alerted the students to difficult passages during pre-reading discussions. Two of the teachers made statements about how the reader will need different strategies for different sections of the book, depending on the difficulty of concepts and the clarity of writing.

While it is difficult to generalize from the limited data in this study, the researchers felt that the preferred model of reading was a reasonable predictor of teaching style. Furthermore, teachers who consciously favor an interactive-constructive model of the reading process were definitely more tuned to the conscious preparation of students on a whole class level, to approach the reading for deeper processing. These teachers also seemed to be more likely to be aware of the variable nature of the comprehension demands of text passages and more inclined to help the students with difficult text passages.

Reading Skills and Comprehension Improvement. Responses to the type of activities used prior to reading the science text (Table 3) indicate that a majority of science teachers report using lectures, demonstrations, media, and previewing text as pre-reading activities. Furthermore, science teachers use class discussion, reports, worksheets, outlines, and graphic overviews as post-reading activities.

Insert Table 3 about here

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Science teachers do not report using reading skill assessments (86.5%) or direct reading skill instruction (73.0%). Science teachers report the use of various reading materials other than the science textbook (63.7%). A minority of scienc teachers (24.8%) report using other techniques designed to improve students' reading. Respondents specifically reported using (number of responses in brackets): vocabulary improvement activities (19), such as crossword puzzles, vocabulary cutlines, and spelling quizzes; general reading plans (16), such as SQ3R, skimming and keywords, text previews and advance organizers; modified textual materials and reading assignments (16), such as current science news reports, tradebooks, directed reading activity cards, oral reading, and differential assignments; metacognitive activities (10), such as externally induced monitoring, summary notetaking, and outlining; cognitive skill instruction (6) dealing with prefixes, suffixes and rootwords, glossaries and indices; and parallel instructional strategies (5), such as debates and writing assignments. These responses indicate that there are a variety of promising practices utilized by a minority of science teachers.

Science teachers expressed concerns regarding science instruction, science reading, and science reading instruction related to the following: lack of instructional time, influence of provincial examinations, science reading will allow student to maintain scientific literacy, trend of science reading ability is down, need for continuing professional education for teachers related to content reading. The interviews and observations indicated that direct science reading instruction was not an ongoing focus for science instruction and that ancillary comprehension activities were used in science classrooms only occasionally by a minority of science teachers. A significant comment by several teachers interviewed is that textbooks tend to benefit better students more than average or lower level students. These teachers recognize that good reading skills lead to better comprehension, achievement, and retention. In this study, teachers who actively acknowledged the correspondence between reading skill level and achievement were most likely the teachers to report providing instruction in reading skills. However, classroom observations in this study did not record any direct reading instruction and little mediated instruction relating to science reading success or efficiency.

Individual science teachers may recognize that accomplishment in science relates to good reading skills, but the school approach to low science achievement and poor reading ability is usually to de-emphasize reading. Usually, when watered-down, slow-stream science courses are developed, they do not focus on building reading skills in the context of related concrete science experiences. Rather they substitute strategies and information sources, such as lecture, copying notes, class hand-outs, discussion, and media, in an attempt to avoid science textbook reading. One teacher expressed the prevailing attitude toward low-level readers in the following statement: "We don't use a book for the slow stream class because they just don't have the reading skills and motivation to learn from a text." The underlying assumption appeared to be that the alternative information accessing approaches were less cognitively demanding than science textbook reading while being equally effective.

When textbooks are utilized for lower-level science courses, they are likely to be chosen on the basis of perceived fit with students' abilities in terms of reading level and content. The selection of lower-level reading materials is usually the only strategy teachers are likely to adopt to deal with the comprehension problems of poor readers. In some science classes, a choice is offered between two books judged to be written at different reading levels. One teache kept a library of multiple copies of several different books. His approach was to direct the students to science content, and the students were given the opportunity to read and/or study any of the textbooks available.

Several teachers of junior secondary science students in this survey recognized the need to adjust science reading material to fit the skills of the reader, but few identified ongoing reading skills instruction as an option and none were regularly able to address the individual needs of students as readers. Science teachers who reported reading skills instruction chose to use whole-class instructional strategies, rather than accommodate students' individual needs as readers with different skill levels. While no teaching approaches or strategies were typical of teachers in the survey, reading skills instruction followed a general pattern. First, reading skills instruction, if offered at all, was presented at the beginning of the course. Reading skills instruction was reported as usually involving instruction on how to access information in books. Often, study skills instruction was a component of the initial instruction; and since most of the content of the course is in the book, text study skills were emphasized. Secondly, students with reading problems were often recognized, but teachers seldom felt that they have the time or skills to help poor readers. Students with distinct reading problems were likely to be referred to learning assistance instructors.

Few teachers feel comfortable teaching content reading skills. One teacher's comment illustrates the basic need for improved teacher educational programs in content reading instruction: "I don't try to teach reading, because I'm not qualified. I wouldn't know how to tell a kid, 'O.K. this is how you go about doing reading'." Although this teacher's statement illustrates an extreme example of lack of confidence, the overwhelming conclusion from the interview/observation study of teachers was that teachers feel deficient in their abilities to teach content reading skills.

The survey and interview responses appear to suppport the need to convince generally willing science teachers that science reading instruction and appropriate use of science textbooks will justify the time expended with increased or equal achievement and provide lifelong access to science understanding. Science teachers need to be made aware of the current thinking on content reading in science and instructional approaches to improve science reading. Presently this information is not found in many science teacher education programs, graduate programs and science education journals.

Planned Changes to Improve Science Reading Instruction and Textbook Useage by Secondary Science Teachers

Successful planned change must identify the areas of concern that will clearly influence desired educational improvements. Then, each factor can be defined in terms of an ideal state and a lowest-level initial state likely to be found in any school system (Leithwood, 1987). The next task is to define a number of intermediate stages representing manageable steps in the direction from the lowest initial level to the ideal state. Finally, the attainable increment of change must be specified. The probability of successful implementation is closely related to identifying attainable incremental changes, to the value placed on the desired changes, and to the support given to the desired changes by the stakeholders.

Secondary science teachers involved in this study have expressed an interest in, acceptance of, and willingness to be involved with changes regarding science reading and textbook useage. These changes appear to be viewed both as natural professional evolution and as having potential for increased learning effectiveness. Few practicing science teachers have had specific education on the major issues of content reading: the interactive-constructive model of the reading process, the cognitive reading skills, the metacognitive reading strategies, and the causes of comprehension failure in reading. Science teachers appear to believe changes in these areas to be promising, untried alternatives to present practice. Furthermore, the resulting improvements in the useage of science texts by teachers and the improved processing of expository text by students will likely result in improved science achievement generally, improved time efficiency of science instruction, and improved life-long access to scientific and technological information. Science teachers believe the first two factors are major considerations in their current teaching situations and curriculum/instruction decisions.

Earlier sections of this article attempted to define an ideal state and current state for science reading instruction and textbook useage in secondary science courses. This section will attempt to describe desirable and attainable changes for a number of important factors related to improved science achievement through improved reading instruction and textbook useage. An analysis of the desired image and current profile identified five main categories of instructional practice and teacher attributes that influence metacognitive and cognitive skills development in secondary science readers and may be sensitive to change: (1) teachers' knowledge about science education, science text, and science reading; (2) teachers' knowledge about science textbooks; (3) instruction aimed at improving students' background knowledge and schema development; (4) direct reading skills instruction; and (5) teacher awareness of, knowledge about, and assessment of reading comprehension. Each of these categories, however, are difficult and professionally sensitive issues to approach directly from the point of view of planned change. This problem has been alleviated somewhat by framing the changes in terms of the image of the student as a successful and efficient science reader.

A careful analysis of the attributes for the student as an efficient, successful science reader suggests many dimensions of educational practice that will influence a plan for improving cognitive and metacognitive science reading skills. Table 4 lists in topical format the dimensions and sub-dimensions felt to be important. A complete listing of the dimensions and subdimensions of the planned change is covered by individual sub-sections contained later in this article.

Insert Table 4 about here

These affective, cognitive, and metacognitive attributes were selected based on their potential for improving science achievement, applicability, responsiveness to instruction, and compatibility with current philosophies of science education (Holliday, 1988; Jacobs & Paris, 1987, Gardener, 1987). Each dimension selected is described on a developmental continuum that reflects the literature and experience. The dimension is briefly described and the initial (1.1), the intermediate (1.2, 1.3, 1.4), and the desired (1.5) states are specified in an ordered series. The data from this study and experience were used to identify a current state(*) and planned change state(**). The change increment is limited to these data and may need modification for specific situations. Approaches to achieve the identified change are briefly described when and where possible. Comprehensive description of in-service programs and in-class instructional treatments are not possible in this article.

I <u>Declarative, Procedural, and Conditional Knowledge About Science Text and Science Reading</u>. It is becoming more and more obvious that science teachers must de-mystify the science reading process and science textbooks. Frequently, science teachers appear to reify concept labels--words. Science words generally are sterile, abstract symbols that only become meaningful and useful if they stimulate memory of associated experiences. The study and manipulation of most language symbols are meaningless and therefore useless, unless the reader has prior experiential knowledge stored in working memory. Furthermore, one must realize that science textbooks are authors attempting to describe or explain science, which is in turn people's attempt to search out, describe, and explain patterns of events in the natural universe. Therefore, science textbooks are interpretations that may be distorted or oversimplified. Accurate science understanding is improved if the reader can construct meaning by integrating personal experience and ideas embedded in text. The de-mystification of science reading and science textbooks has some rather pointed suggestions for science teachers regarding the design of science courses and the selection of instructional practices.

IA Emphasis:

IA1 Problem Solving, Nature of Science, Secondary Science Courses and Science Text

Secondary science should reflect the scientific enterprise and should be viewed as far more than simply the content of a discipline as summarized in a single textbook. Science is seen as a reflective process encompassing many aspects of critical thinking, problem-solving, inquiry, and decision making useful to educated citizens.

IA1.1 Science is viewed as the content of the text. Learning involves decoding and memorizing the text.

IA1.2 Science is viewed as something more than text content, but the text is the only practical source of science information for students. Reading skills are useful but this is not the responsibility of science teachers.

*IA1.3 Science is more than text content, but text content still shapes the course. Reading skills help students in science but other factors are equally important, all of which deserve attention.

**IA1.4 Science is recognized as a complex problem-solving approach, involving many skills essential to citizens. Efficient reading helps science learning, is essentially a problem solving, inquiry and decision-making process that parallels science, and teachers must take responsibility to help students improve reading.

IA1.5 Science is far more than text content, and is an essential problem-solving approach. Efficient reading helps students learn science and grow in the image of educated people.

IA2 Balanced Goals of Secondary School Science Teaching/Learning

Science teaching/learning is viewed as selecting a balance between teaching science content (the information that science has developed), affective attributes (the emotional dispositions and personal characteristics of the scientific enterprise), science process (the understanding about how science reveals information about the world), scientific thinking (critical, rational, and creative thinking), and learning about learning (the understandings that students develop from examining their own science thinking and learning). Reading as a metacognitive ability involves and is important to all five aspects of science teaching/learning.

IA2.1 Science teaching involves organizing students to read and learn the content of a text. Science learning is reading the textbook. Reading is facilitated by the proper selection of a science textbook.

*IA2.2 Science teaching/learning is text learning and process skills. Reading skills can help science learning, but reading instruction is not science teaching.

IA2.3 Science teaching/learning involves a blend of the content of science and learning about how science is done. Reading is essential to learning science but teaching reading is not the major responsibility of science teaching.

**IA2.4 Science teaching/learning blends content and learning about doing science. Helping students to read better will help them learn science content.

IA2.5 Science teaching/learning is balancing content, affect, science processes, thinking, and learning about learning. Efficient reading is essential to and results partially from all five components.

IB Values:

IB1 Importance of Learning How to Learn

Metacognitive goals are viewed as interwoven with scientific literacy, cognitive skills, and discipline knowledge. Effective teaching for metacognition improvement required teaching students about the function of cognition/metacognition during the reading, thinking, and learning processes, as well as teaching students about the function of discipline-specific knowledge involved in learning science.

IB1.1 Discipline knowledge, as outlined in a science text, is the focus for all science teaching/learning. Teacher-directed task identification and assessment promote effective science achievement.

*IB1.2 Discipline knowledge from texts, science processes, scientific attitudes, understanding of scientific inquiry are the main interests of science teaching. Effective teaching is selecting a variety of teaching/learning experience to match the learning outcomes.

IB1.3 Students can effectively learn science content, attitudes, and processes and about how science is carried out without addressing ideas from thinking and learning theory.

**IB1.4 Students learn about science content and doing science by knowing something about how they acquire knowledge, make discoveries, and construct understanding.

IB1.5 Metacognitive skills interweave with cognitive skills and discipline knowledge. Students should learn about all three during instruction. Learning theory instruction will aid learning reading skills.

IB2 Importance of Lifelong Learning

Success in science learning is related to more than students' abilities to perform well on measures of science content knowledge. Students' abilities to read and comprehend science reading materials are skills for lifelong learning and extremely important implications for the image of the educated person.

IB2.1 Tests of students' abilities to recall text information are sufficient measures of science learning.

*IB2.2 Text information tests may not assess students' learning of some aspects of science, but they are the only practical approach and are generally sufficient.

IB2.3 Measures of science learning must extend beyond information recall, but reading is not a valid measurement source of science learning.

**IB2.4 Science learning may be measured with a variety of means. Science reading comprehension may form a small component of measurements addressing other factors.

IB2.5 A variety of measures of science learning are required, including measures of attitudes, knowledge, process, skills, thinking and efficient science reading. Reading measures should be assessments of metacognitive and cognitive abilities.

IC Growth:

IC1 Development of Secondary School Science Reading

The teacher has a conceptualization of the growth of students as readers during secondary school science courses that includes: growth of abilities to set purposes for the reading and to choose strategies for reading according to the purpose; growth of comprehension monitoring skills; growth of the ability to use automatic comprehension monitoring normally, but to exercise conscious monitoring control when comprehension is blocked; growth in self-confidence about the success and benefits of the reading process; and growth in the development of cognitive skills for the reading and in the ability to choose appropriate cognitive skills to fit the demands of the reading.

IC1.1 Students have basic reading skills upon leaving elementary school.

IC1.2 Some students do not have basic reading skills upon leaving elementary school. They may improve with practice and without direct instruction, therefore reading assignments are the remediation approach of choice.

*IC1.3 Students can experience difficulties with reading. Science text presents many difficulties. Teachers should be aware of the difficulties but do not have time to teach reading skills.

**IC1.4 Growth in reading skills promotes growth in science learning. Teachers should provide instructional help to poorer readers.

IC1.5 All students grow in their metacognitive reading abilities, and teachers should plan direct content specific instruction around a view that reading growth in secondary school is normal and should be actively promoted.

IC2 Compatibility of Learning Level and Instructional Level

The teacher matches the level of the reading tasks' difficulty and direct reading instruction to the stages of development of the students' cognitive and metacognitive reading abilities based on diagnostic assessment and ongoing monitoring. Reading tasks and instruction are adjusted to meet the individual needs of lower-level readers while challenging and providing enrichment for better readers.

IC2.1 Readings from the prescribed text are the essence of students learning science.

IC2.2 All students should be able to learn from the prescribed text, but some students will require more coaching or guidance.

*IC2.3 Many students are not ready to learn from text readings. Lessons are planned so that students can get the material entirely from lectures if they attend and take notes.

**IC2.4 Students vary widely in their abilities to learn from text or from other approaches. But reading is essential for lifelong learning. Level-specific reading tasks are provided. Reading growth is promoted informally.

IC2.5 The teacher assesses each student and monitors growth in reading skills. Reading tasks are adjusted to the levels of students. Direct instruction is provided to promote the acquisition of cognitive and metacognitive abilities. All students are challenged to grow as readers.

ID Selection Criteria For Instructional Materials and Strategies:

ID1 Teacher's Model of the Reading Process

The teacher views the reading process as a complex interaction between the reader and the text involving the application of cognitive skills and metacognitive strategies by the reader to construct (invent) meaning that fits both the interpretation of the words and the cognitive frameworks residing in memory or readers' restructured cognitive frameworks. The teacher keeps in mind the need to assess students' cognitive frameworks and background knowledge before reading assignments are prescribed.

ID1.1 Text words determine the information that the student learns during reading. All the required information should be in the text.

ID1.2 Most of the information needed to understand the text is there, but some students may need some help with words or concepts.

*ID1.3 The students should have a good background of the concept under consideration. Then the reading will serve to help organize what they have already learned.

**ID1.4 Teachers often prepare students for readings. They provide background or overviews of readings, directing students toward getting more out of the reading. They design readings, instruction, and assignments to build on other cognitive structures.

ID1.5 Teachers view the reading process as both interactive and constructive. Teachers always assess background schema before reading, provide requisite experiences and teach self-assessment skills. Cognitive demands of readings are assessed.

ID2 Teacher's Conceptualization of a Good Science Reader

The teacher has a conceptualization of the blocks to comprehension that may be experienced by readers. This conceptualization includes knowledge of factors in the text, such as word difficulty, syntax complexity, text structure, passage coherence (clear connectives, unambiguous pronoun referents, etc.), concreteness, and ease of imaging. Factors related to the reader's motivation, self-confidence, attention directing skills, and sense of purpose for the reading are included. Students' background knowledge and schema are considered as potential sources of problems, as are students' development or lack of development of metacognitive abilities, such as self-appraisal and self-management of cognition.

ID2.1 Students who do not learn from the text are lazy. They should all be able to learn from the text.

ID2.2 Some students are slower readers, or they do not have the necessary reading skills. Text difficulty is part of the problem. Dealing with reading problems is not part of science teachers' responsibility.

*ID2.3 Several factors are recognized as contributing to reading problems, but these are not well-understood, and the teacher largely feels that dealing with these problems for specific students is beyond their present ability.

**ID2.4 Teachers have a moderately refined understanding of blocks to reading comprehension. They attend to many of the implications and factors in their instruction about the text and about some reading skills.

ID2.5 Teachers understand the blocks to comprehension, including specific text factors, factors related to students' motivation and purpose, their cognitive background, and their metacognitive strategies. Direct instruction reflects an attention to these factors.

These desired changes will occur when science educators, science teachers, and science publishers critically analyze the science education process. Many conflicting points are expressed by these stakeholders, and they generally take adverse positions. Often these opinions are not motivated by the desire to improve science achievement for female and male students. Vested interests frequently cloud the agenda of implementing theory into practice in an attempt to improve the process of science education.

II Declarative and Procedural Knowledge About Science Textbooks

Knowledge about, rationale for, and facility with textbook attributes, such as organization, location devices, adjuncts and expository text structure, are prerequisites to efficient, effective science reading. These attributes vary drastically between content areas and between science textbooks for a specific discipline, and demonstrate little variability within a single science textbook or science textbook series. Social studies textbooks rely on temporal sequences, descriptions, and enumeration far more frequently than physics textbooks, which rely heavily on cause/effect, problem/solution and compare/contrast structures. Authors, editors, and publishers have their unique ways of organizing, designing, and structuring science textbooks, but managing editors consistently apply these methods throughout a single textbook and textbook series.

Information access systems require knowledge about the data storage to select, develop, and execute effective information retrieval procedures (Beers, 1987). Computers have du l and exact memories, whereas the mind has a poor memory in which information input is selectively retained and altered. Science reading and remembering are no different. Meyers (1975) found that readers with knowledge about expository text structures demonstrated greater reading comprehension than readers without such information. Skilled readers use text structures and other textbook features to extract higher order ideas and construct meaning. Textbook attributes guide encoding, recalling and reproducing essential ideas, and meaningful learning.

IIA Textbook Structure:

IIA1 Science Textbook's Choices and Priorities

Realizing that science texts and reading materials have widely varying cognitive demands, the science teacher chooses text and supplemental readings appropriate to the cognitive/metacognitive skills of the readers and the stages of their development as readers. The teacher alerts students to more difficult readings and provides opportunities for students to read topical text material with lower cognitive demands. Furthermore, the teacher priorizes science content by selecting text information on the basis of the balanced view of science instruction and on the basis of a logical development of background knowledge that will allow readings to be more efficient and successful.

IIA1.1 The teacher strictly uses the entire prescribed text on a once-through basis.

*IIA1.2 The teacher selects text passages of importance. These receive greater student attention.

IIA1.3 The teacher attempts to prepare all students for the general text reading. Text passages are scanned for readability and value to the student.

**IIA1.4 The teacher provides general reading instruction for all students to develop requisite skills for the text and provides directed reading activities for difficult passages or provides alternative texts for lower readers.

IIA1.5 The teacher carefully monitors the cognitive demands of reading choosing appropriate text passages, working in class with difficult passages, providing direct reading instruction requisite to text demands, and generally correlating student learning success with text difficulty.

IIB Text Marco-structures:

IIB1 Ancillary Textual Materials

Supplemental or substitute reading materials for science texts are used at appropriate times, including: newspaper and magazine articles, historical or bibliographical information, limited primary literature, and other sources. Supplementary readings can provide: personal relevance for science reading, a context that places science concepts in everyday life, inspiration and motivation to learn science concepts, and perspectives or summaries that are not typically found in science texts.

IIB1.1 Only the text is used.

*IIB1.2 The prescribed text is used almost exclusively, but occasional outside readings are used.

IIB1.3 Teachers try to relate science material to the lives of students, and frequently bring in science news or articles. These are often treated as science text.

**IIB1.4 Students use science news and articles they and the teacher find to learn science. They learn to read critically, assessing contextual influences, motives, and bias.

IIB1.5 Students are often involved in critical reading of science material other than text and develop components of scientific literacy that apply to lifelong learning.

IIC Textbook Features:

IIC2 Adjunct Support Materials

The science teacher chooses visual aids and audio-visual instruction to complement text readings and to promote interest and motivation for science readings. Instructional aids are used as previews of readings, summaries of readings, or replacements for readings, as appropriate.

IIC2.1 The text is used exclusively.

IIC2.2 Audio-visual aids are seldom used and rarely used in concert with specific strategies for reading.

*IIC2.3 Audio-visual aids are frequently used but only occasionally in close relationship to reading. Reading information is seldom evaluated against information from other sources.

**IIC2.4 Audio-visual aids are often used where appropriate as reading adjuncts. Some comparison of text information and other information is made.

IIC2.5 Audio-visual aids are often used with purposes related to reading objectives. Students often critique the information presented and measure it against text information. They have frequent opportunities to assess the fit of such aids to their learning preferences.

Early and continuous, direct instruction about textbook attributes, how to use these features, and when to use the feature that is regularly reinforced and applied has significant impact on readers' metacognitive abilities to locate main ideas, recall text, and generate summaries (Winograd, 1984; Taylor, 1986; Meyer, Brandt & Bluth, 1980; Barnett, 1984; Armbuster, Anderson & Ostertag, 1987). Yore (1984) developed group inventories of these skills and specific activities for textbook organization (table of contents), location devices (index), meaning aid (margin definition and glossary) that could be adapted to other science textbooks. Armbuster, et al (987) provided a comprehensive description of text macro-structure learning activities for social studies that could be modified and expanded for science and other appropriate science macro-structures.

III Direct and Explicit Teaching Strategies That Stress Compatibility Between Science Education and Science Reading instruction

This study revealed five things regarding the teaching strategies utilized in secondary science classrooms, specifically (1) a rather limited set of strategies are woven together deductively; (2) lecture, reading, or note copying are the major information access methods utilized; (3) reading textbooks is used to reinforce and enrich concepts initated by other means; (4) answering in-text questions is utilized to improve comprehension; and (5) few science teachers provide direct skill instruction or ancillary activities to improve reading. Jacobs and Paris (1987), Pearson and Dole (1987), and Yore (1984) have provided informative reviews of direct instruction regarding global and specific reading skills. Pearson and Dole (1987) point out that effective instruction must clearly model, practice, and apply the new skill with a distinct transfer of ownership of the skill from the teacher to the student. Jacobs and Paris (1987) pro ded specific strategies deemed promising in science reading. Yore (1984) described several techniques to improve specific cognitive reading skills.

IIIA General Teaching Strategies:

IIIA1 Strategies Emphasizing Procedural Knowledge

The science teacher chooses instructional sequences associated with reading assignments that are designed to provide: access to establishe prior knowledge, concrete science experiences to which the student will be able to relate concepts and ideas from the reading; motivation for the reading and a clear perspective of its purpose, including focus points or questions; the possibility of aids to help the students monitor the comprehension progress of the reading (higher-order questions and student-generated questions are two examples of such aids); frequent feedback for students about their success in reading comprehension; and opportunities for each student to self-assess their reading comprehension and remediate identified problems (margin notes, small-group discussions of key concepts, peer tutoring, or written summaries are among the possible approaches).

IIIA1.1 The teacher uses instructional sequences in a non-integrated or convenient way. Text readings often come at the beginning of sequences. Text questions or rote outlining are often the methods used tc force the reading.

*IIIA1.2 Instructional strategies reflect a view of learning where the text may play an important, but not the exclusive, role in learning. Readings may follow preparatory activities, such as vocabulary study, review of previous lesson, or other drill/practice approach.

IIIA1.3 Instructional sequences are designed to build a broad procedural knowledge base so that text readings are more effective and can consolidate what the students know.

**IIIA1.4 Instructional sequences are carefully designed to promote more learning from readings. Pre-reading and post-reading activities are frequently used. Instruction is varied and motivational.

IIIA1.5 Instructional sequences are designed around an extensive picture of the process of reading. Activities precede readings to motivate, focus, access prior knowledge, establish appropriate schema, and generally prepare students. Comprehension monitoring, look-back, and summation skills are encouraged during reading. Strategies for higher-order learning and self-assessment are included as are post-reading activities.

IIIA2 Strategies Emphasizing Content Specific Background Knowledge

The teacher uses instructional strategies, before a reading assignment, designed to assess students' knowledge and content specific schema critical to literal and applied comprehension of the reading assignment, to provide necessary background and to construct knowledge links between ideas. The instructional strategies should involve active search of schema, experiencing an interactive-construction of knowledge on the part of the students rather than passive input of information. Among the techniques included in this category are graphic overview, concept mapping, and other advance organizers, brainstorming, and preview of text.

IIIA2.1 Teachers only assess whether students have learned from a reading.

*IIIA2.2 Teachers may often give background lectures, sometimes asking questions to assess if the students are learning the material.

IIIA2.3 Teachers usually provide thorough background preparation, often with monitoring of student learning. This is often directed toward a reading but not with expectations that the reading will expand or clarify the lectures.

**IIIA2.4 Teachers prepare students for readings. They often assess cognitive structure. They help students to build appropriate background knowledge.

IIIA2.5 Teachers choose strategies to assess cognitive structures, remediate background deficiencies, motivate, build overviews, and generally make readings more successful.

IIIA3 Strategies Emphasizing Vocabulary Background Knowledge

The teacher uses strategies to provide and clarify technical and non-technical vocabulary essential to comprehending reading assignments. Vocabulary is presented with contextual information, in relationship to other words, or in relation to previously-learning concepts. Mnemonic devices, visual imaging, word webs, and other techniques are utilized to help students remember essential vocabulary. Techniques for word defining are used, such as root-word analysis, context indication, glossaries, and dictionaries.

IIIA3.1 No vocabulary background is provided.

*IIIA3.2 Students often get preview or review of vocabulary but they do not learn skills for determining meanings.

IIIA3.3 Vocabulary is emphasized, and students learn some basic deciphering skills.

**IIIA3.4 The teacher usually deals with difficult vocabulary. Several vocabulary skills are used. Vocabulary is a main focus for pre-reading activities. Students learn deciphering vocabulary from root analysis.

IIIA3.5 Vocabulary skills in science reading are essential. Vocabulary is treated with a variety of methods, designed to help students build long-term vocabulary skills.

IIIB Direct Instructional Strategies:

IIIB1 Direct Instructional Strategies for Metacognitive Skills

The teacher gives an instructional sequence in skills for reading comprehension appropriate to the development of the students as readers. The instruction includes perspectives on the problem-solving nature of reading comprehension, the role of cognitive strategies, and the role of comprehension monitoring.

IIIB1.1 Students receive no reading instruction.

*IIIB1.2 Reading instruction is seen as possibly of benefit to students but not part of teaching science. Students may be encouraged to read or learn to read well. Poor readers may be directed to learning assistance teachers.

IIIB1.3 Students receive a minimum of basic reading skills instruction at the beginning of the year. Further reading skills instruction is usually viewed as not feasible due to demands of coursework. Very poor readers are directed to learning assistance teachers.

**IIIB1.4 Students learn general reading plans and self-management skills to promote reading at the beginning of the course.

These may be reviewed later. Science reading skills may be emphasized as well as study skills.

IIIB1.5 Based on assessments of science reading skills, the teacher plans an integrated, continuous approach to teaching and monitoring students' metacognitive development as efficient science readers.

IIIB2 Direct Instructional Strategies for Text Structure

The teacher gives instruction in recognizing and understanding various text structures found in expository science texts. The instruction includes techniques for efficiently comprehending various text structures. The ability to recognize text structure and deal with it appropriately is monitored at appropriate times during the course.

IIIB2.1 Science text is generally viewed like other reading material. No instruction is given in approaches to reading science.

*IIIB2.2 Science reading is recognized as being more difficult, but its properties are not realized. Students are often encouraged to read science materials several times, as a better way to understand.

IIIB2.3 Students learn to be aware that science reading requires attention to detail. They may learn about text structure, but most attention is usually on main ideas without specific regard to structure.

**IIIB2.4 Students learn about text structures, and how they are used in science writing. They practice identifying and summarizing structures.

IIIB2.5 Students learn to recognize text structures and to adopt specific strategies for dealing efficiently with different structures. They learn to use such structures for writing, reading, and studying.

IIIB3 Direct Instructional Strategies for Study Skills

The teacher gives instruction in skills for reading-material studied in a long-term sequence that includes feedback, practice, and review. The value of study skills to student comprehension and student assessment is emphasized.

IIIB3.1 No study skills instruction.

*IIIB3.2 Study skills instruction emphasizes rote.

IIIB3.3 Study skills instruction is provided for students that emphasizes review of class notes and is narrow in its scope. It is usually only given at the beginning of course.

**IIIB3.4 Study skills instruction is long term, recognizing different study demands of different texts and for different purposes.

IIIB3.5 Study skills instruction is integrated throughout the year. It focuses on many aspects of study and reading for remembering. It leads students toward choosing from a variety of stategies to fit their study needs and regular application of studying.

IV Declarative, Procedural, and Conditional Knowledge About Assessment of Science Education and Science Reading Objectives

Two major influences in science instruction appear to be related to assessment issues. Science teachers sense a good deal of pressure for teaching strictly to the knowledge base because of provincial/state examinations that stress science knowledge. The second problem is related to the limitation of traditional paper and pencil examinations. Since this media is best suited and frequently used to assess lower level cognitive knowledge, the objectives of the science courses are revised to emphasize lower level cognitive knowledge rather than thinking and other higher level skills.

IVA1 Timing:

IVA1 Long Range Planning of Assessment

The teacher carries out reading comprehension assessments for science expository science text at the beginning of the course and at appropriate intervals during the course. Strategies to remediate comprehension difficulties are planned on a long-term basis, and specific reading instruction is integrated into science content at opportune times.

*IVA1.1 No reading instruction or assessment.

IVA1.2 Reading instruction only at the beginning of the year. No assessment.

IVA1.3 A qualitative assessment is carried out to recognize lower readers, and some remediation is planned for them. Instruction is usually frontend.

**IVA1.4 An assessment of all readers is carried out. Reading instruction focuses on lower readers but is also directed at others. Instruction is viewed on a longer-term basis.

IVA1.5 All readers are regularly assessed, and science reading

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instruction attempts to remediate difficulties and considers appropriate advanced skills and strategies.

IVB Procedures and Growth:

Science teachers need to realize that science reading skills improvement is a gradual process, and it progresses from less demanding skills to more demanding strategies.

IVB1 Reading Comprehension

The teacher uses various procedures for assessing reading comprehension skills, such as cloze procedures, written summaries, main idea analysis, and word-from-context ...es. The reading comprehension assessments are designed to monitor growth in reading comprehension and to evaluate the effectiveness of reading skills instruction.

IVB1.1 No reading skills assessment.

*IVB1.2 No reading skills assessment but the teacher recognizes the value of varying the type of questions students are asked to yield data appropriate to varied approaches of reading.

IVB1.3 Teachers use initial assessments of reading skills, and they keep track of lower level reader progress using one or two measures.

**IVB1.4 Teachers keep tabs on students' reading ability growth by monitoring one or two measures at a few points in the year.

IVB1.5 The overall program of reading assessment and monitoring involves use of several measures as outlined above.

IVB2 Higher Order Strategies

Assessment of science content learning involves assessment of higher order learning appropriate to the level of cognition required by the reading material and consistent with the students' development as readers. Students are expected to provide more than just recall of text information, and they should receive feedback on reading comprehension through science content assessments (Bareiter & Scardamalia, 1987).

*IVB2.1 Text questions are used exclusively. Easily marked questions are preferred.

IVB2.2 Teachers select a mixture of questions, based mainly on content assessment.

IVB2.3 Higher order questions usually aimed at skills other than those associated with reading.

**IVB2.4 Higher order questions are often used to assess higher order skills application in reading.

IVB2.5 Higher order questions are often used to assess strategic knowledge, planning, monitoring, and managing skills.

Summary

The interpretation of this study indicated that teachers are willing to consider professional development activities directed at improving the use of science textbooks and science reading instruction. It must be realized that such professional development will influence classroom practice gradually and will require substantial effort. The recommendations provided stress incremental change and attempt to describe future increments required to fully realize the potential of science reading. The implementation of these recommendations must realize that several obstacles need to be overcome by using specific strategies. The following lists associate specific obstacles with mediation strategy.

Obstacle	Strategy
Teacher unfamiliarity with	
1. Reading models	. Workshops, professional science journals, and small publications from school district
2. Reading assessment strategies	. Ministry or Department of Education development of assessment tools
	. Peer exchange
	. Improvements in teacher education
3. Skills instruction	. Ministry or Department of Education and school district workshops
	. Improvements in teacher education
4. Comprehension problems	. Ministry or Department of Education and school district workshops
	. Assessment procedures
	. Improvements in teacher education
Conflicting needs of curriculum	
1. Time	. Re-evaluation of curriculum emphasis
	. Re-assessment of efficiency of lifelong learning in science

2 Content	. Establish priorities, Ministry or Department of Education and locally
Conflicting needs of exams	. Re-evaluation of examination purposes and assessment categories by Ministries or Departments of Education
	. Evaluation of the effects of examinations on reading skills and study skills
Support from Administration	. Promotion from Ministry or Department, University and School District Level

This paper was designed to stimulate improvement in science education and provide an innovation profile for planned change in the area of secondary science reading comprehension that considers science textbook useage and science instruction. However, science education at the secondary level is not necessarily totally poised for change. Despite ongoing research into the learning process, despite recent developments in instructional technologies, despite occasional surges of interest in hands-on and discovery science, and despite the excitement of science portrayed in the media, science education has developed and maintained a static approach to helping students learn science. In terms of education, science has become the information contained in a relatively few science texts. Thus, in the context of current secondary science education, improvements in the use of textbooks and in students' abilities to comprehend science text material should, at least theoretically, lead to improvements in overall achievement in measures of text-based science learning. While this may be a desirable outcome for many teachers, the solution must clearly extend far beyond the desire to make text-based learning more efficient to science instruction in which the textbook is just one of many components in an interactive-constructive system that allows learners to experience, interact, and invent appropriate and accurate understandings while promoting thinking and self-regulating skills.

The vision guiding this innovation profile is the image of an educated person - an image not yet clearly in focus, as such images require looking ahead to the elusive lifelong learning skills people will need in their lives after public school. Science learning in various forms can become a lifelong activity. The role of metacognitive skills in that activity cannot be questioned. Science reading especially can be recognized as an absolutely essential element of lifelong science learning. Like learning in general, science reading is a complex task requiring the efficient application of many problem-solving or metacognitive strategies. On the other hand, no one can deny that science experience plays an important role in science learning; it is the background information and concepts that can trigger an interest, stimulate a desire to learn something new, or provide a framework for understanding difficult ideas and concepts often associated with science topics.

The key element to creating change in science education may ultimately reflect our desires to find a better balance - to create a science education environment that encourages as many students as possible to develop lifelong interests in learning science. For this, students need to learn about learning, they need to learn about how and why science functions, and they need to acquire basic concept and information foundations upon which to build their developing knowledge of science. The goal of this study has been to shift the lopsided, text-based, content-dominated approach of current science education towards a more encouraging balance.

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Table 1

Science Teachers Assessment of Teaching/Learning Effectiveness of Specific Instructional Activities (Percentage Response)

	Most Effective					Least Effective	No Response
Simulations & Games	10.7	9.8	11.3	14.0	24.3	23.4	6.5
Demonstrations	52.8	26.2	10.3	4.7	1.4	0.5	4.2
Reading	3.7	13.1	39.3	21.0	11.2	7.5	4.2
Debates & Role Plays	1.9	5.6	5.1	12.1	24.3	43.9	7.0
Lectures	23.4	29.9	15.4	9.3	9.3	8.4	4.2
Individual & Small Group Reports	3.7	11.7	15.0	33.6	20.1	10.7	5.1
Structured Laboratories	54.2	20.6	10.7	5.6	4.2	0.0	4.7
Field Studies	16.4	21.0	15.9	14.0	15.4	11.7	5.6
Computers	0.9	4.7	11.7	16.8	23.8	35.5	6.5
Case Studies	10.7	16.4	18.7	14.5	17.3	17.3	5.1
Media	4.2	15.0	15.0	21.0	21.0	18.2	5.6
Unstructured Inquiry	3.3	5.6	3.3	4.7	11.2	66.4	5.6
Models	9.3	12.1	15.4	21.0	28.0	8.9	5.1
Class Discussions	17.2	20.6	24.8	16.8	12.1	3.3	5.1

ERIC Full Text Provided by ERIC

Table 2

Science Teachers Sequential Placement of Specific Instructional Activities in a Lesson (Percentage Response)

Learning Activity	Position within a Lesson 1	2	3	4	No Response
Reading	13.0	18.6	25.6	36.3	6.5
Laboratory	20.0	30.2	25.6	17.7	6.5
Class Discussion	21.9	21.4	22.8	27.9	6.0
Lecture-Demonstration	40.5	22.8	19.1	11.2	6.5

Table 3

Activities used in conjunction with Science Text (Percentage Response)

	Always use	Frequently use	Occasionally use	Seldom use	Never use	No Response
Pre-reading Activities	9.8	27.0	25.1	9.8	5.1	23.3
word webs	0.5	1.4	14.0	26.5	47.0	10.7
lectures	21.4	57.7	15.3	2.8	0.9	1.9
demonstrations	10.7	69.3	16.7	0.9	1.4	0.9
media	1.4	35.8	44.7	12.6	2.8	2.8
preview of text	8.4	31.2	28.8	17.7	9.3	4.7
Post-reading Activities						
discussions	28.8	53.0	13.5	0.9	1.9	1.4
reports	3.3	21.9	47.4	19.5	5.1	2.8
worksheets	12.6	53.5	26.5	3.7	1.4	2.3
outlines	8.4	26.5	34.4	17.2	9.8	3.7
graphic overview	3.3	28.4	30.7	16.3	14.4	7.0

Table 4

Dimensions and Sub-dimensions of the Planned Change

I **Declarative, Procedural, and Conditional Knowledge About Science Text and Science Reading**

- IA Emphasis:
  - IA1 Problem solving, nature of science, secondary science courses, and science text
  - IA2 Balanced goals of secondary science teaching/learning
- IB Value:
  - IB1 Importance of learning how to learn
  - IB2 Importance of lifelong learning
- IC Growth:
  - IC1 Development of secondary science reading
  - IC2 Compatibility of learning level and instructional level
- ID Selection Criteria for Instructional Material and Strategies:
  - ID1 Teacher's model of the reading process
  - ID2 Teacher's conceptualization of a good science reader

II **Declarative and Procedural Knowledge About Science Textbooks**

- IIA Textbook Structures:
  - IIA1 Science textbook choices and priorities
- IIB Text Marco-Structures:
  - IIB1 Ancillary textual materials
- IIC Textbook Features:
  - IIC1 Adjunct support materials

III **Direct and Explicit Teaching Strategies that stress Compatibility between Science Education and Science Reading Instruction**

- IIIA General Teaching Strategies
  - IIIA1 Strategies emphasizing procedural knowledge
  - IIIA2 Strategies emphasizing specific background knowledge
  - IIIA3 Strategies emphasizing vocabulary background knowledge
- IIIB Direct Instructional Strategies:
  - IIIB1 Direct instructional strategies for metacognitive skills
  - IIIB2 Direct instructional strategies for text structures
  - IIIB3 Direct instructional strategies for study skills

IV **Declarative, Procedural, and Conditional Knowledge About Assessment of Science Education and Science Reading Objectives**

- IVA Timing:
  - IVA1 Long range planning of assessment
- IVB Procedure and Growth:
  - IVB1 Reading comprehension
  - IVB2 Higher-order strategies