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ABSTRACT

This study was designed to develop effective and time efficient assessment techniques for self-appraisal of science text and science reading and to assess middle grade students' metacognitive knowledge about science text and science reading. Standardized interviews, word associations, concept maps, and objective examinations were administered to grade 5 students. Preliminary results of the interviews reveal that grade 5 students have reasonable declarative, procedural, and conditional knowledge about science text and science reading but much growth is needed for them to become efficient, successful science readers. These results identify metacognitive dimensions regarding science text and science reading that would be strengthened by explicit instructions designed to improve students' knowledge of the use of science text. Reciprocal teaching was also identified as a promising instructional strategy that provided the support required to develop self-appraisal skills. A list of 64 references is included and structured interview protocols, structured tests for assessing self-appraisal of science reading and science text, a form for concept mapping, and a set of word associations are appended. (CW)

A Preliminary Report:

An Assessment of What Grade 5 Students Know About Science Text and Science Reading

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Introduction

A historical review of science curricula reveals major philosophical changes reported in the literature: the 1940's dominated by textbooks with a natural history and science applications focus, the 1950's with traditional content focussed texts, the 1960's with inquiry based science, the 1970's with reactionary reflex to a content discipline approach, and the 1980's with a science-technology-society (STS) focus. Throughout these fifty years little has changed in the majority of elementary classrooms regarding science instruction -- science is infrequently taught, textbooks dominate the instructional decisions, and biological topics represent the major area of consideration. The 1990's present an excellent opportunity to drastically influence science instruction in the elementary and middle school classroom. Numerous factors--like the STS movement, AAAS 2061 proposal, research results regarding construction of knowledge, interactive-constructive model of reading, cognition and metacognition, and thirty years of successful inquiry-oriented instruction--provide a broad foundation on which to plan change.

Background

According to Holliday (1984), reading is one of the most frequently used methods for science instruction. The insructional sequence is dictated by the textbook. The typical sequence is assign, recite, test, discuss test (Yager, 1983). He also stated that most instruction in science centers upon the mastery of unique words and terms with little attention to meaningful understanding. Harms (1981) and Stake and Easley (1978) pointed out that 95% of science teachers use textbooks 90% of the time. Pratt (1981) agreed that elementary school science instruction is driven by textbooks. With such extensive use of textbooks for science instruction, several questions beg to be considered (Yore, 1986a). What do science teachers know about the reading process generally, science reading specifically, and science text? Do teachers use this knowledge in designing instruction? Do science teachers know what their students know about science reading and science textual materials? Do science teachers provide explicit instruction to increase science reading skills and knowledge about science reading and science text?

Generally speaking, elementary science teachers' views of reading coincide with current approaches to reading (Shymansky, Yore & Good, in press). Reading is no longer viewed as a matter of extracting meaning from print. Comprehension is no longer regarded as a myriad of subskills. Factors influencing comprehension may be inside the head and outside the head (Samuels, 1983; Schell, 1988). Inside the head factors include prior knowledge, interest, ability, strategy use, linguistic competence, and goals. Outside the head factors include text topics, text structure, and situational context. If one factor is changed, so is comprehension.

Reading is presently portrayed as interactive/transactive (Guthrie, 1981; Langer & Smith-Burke, 1982; Spiro, Bruce & Brewer, 1983) and constructive (Langer, in press; Rumelhart, 1980; Spiro, 1980a). Readers interact/transact with text and context to construct meaning. The context includes the situation, the linguistic context, interest, and attitude. Valencia and Pearson (1987) viewed readers as active learners who use clues from text in concert with their prior knowledge, environmental clues, and social context to construct meaning.

The present view of reading focusses on how the reader builds meaning from print. Comprehension is considered to be an on-going process of understanding that grows and changes as the reader proceeds through the text (Collins, Brown & Larkin, 1980). According to Shymansky et al. (in press), the interactive-constructive model of reading "encapsulates Piaget's importance of experience, Vygotsky's importance of language, and Karplus' importance of exploration, invention and application" (p. 3).

Although elementary science teachers generally agree with the current view of the reading process, Shymansky et al. (in press) indicated that little was known about teachers' attitudes toward and knowledge about science reading instruction. They suggested that teachers know little about the unique features of expository text. Yore and Denning (1989) found little evidence in secondary science classrooms of informed science reading instruction or science textbook utilization that reflected current models of reading.

Science Education

Most science educators would agree that elementary and middle school science learning involves an active exploration of concrete events by students who in turn construct understanding of these events utilizing a variety of intellectual processes. Science teaching should facilitate this process by engaging misconceptions, providing meaningful experiences, guiding the construction process with a supportive scaffolding, connecting new constructions with recorded discoveries, and developing requisite skills, abilities, and processes. Generally, effective science teaching can be considered as replacing one misconception with another conception, where the second conception is more accurate than the first misconception.

Meta-analysis of the 1960 science curricula research results indicated that the learning cycle approach was effective in improving students' achievement, thinking, and process skills (Shymansky, Kyle & Alport, 1983). Yore (1984, 1986b, 1986c) found that structured inductive and semi-deductive inquiry could be successfully used with specific groups of elementary school learners. Lawson, Abraham, and Renner (1989) reported that the structure and sequence (explore, invent, apply) of the learning cycle were critical. Shymansky and Yore (1980) reported that science instruction should provide a problem focus, a concrete experience, a scaffolding for construction of understanding, and opportunities to enrich, expand, and reinforce learning.

Science Text

Reading a text book is an integral part of most science classes. Unfortunately, factors related to both reader and text make the understanding of science textual materials a difficult undertaking for many students. Because of repeated exposure to narrative text (fiction) and because narrative text has a consistent text structure (setting, beginning, development, ending), students develop a schemata or cognitive framework that helps them to construct meaning from narrative text (Stein & Glenn, 1979; Stein & Trabasso, 1982). Students have not been exposed to the same quantity of expository (subject matter) text. In addition, expository text does not have a consistent text structure (Mulcahy & Samuels, 1987). The structure of science text can be description, collection, compare-contrast, causation, or problem solution (Meyer & Rice, 1984; McGee & Richgels, 1985). Besides possessing an unfamiliar and inconsistent text structure, science text exhibits other unusual features, such as unique lexicon, semantic features and syntax, which lead to students' difficulties in understanding science text (Eisenberg, 1977; Flood, 1986). Expert learners are aware of the purpose of expository text, its grammatic features, structure and adjunct devices, and use them appropriately in the reading process (Brown, 1982; Samuels, 1983; Steward & Tei, 1983). However, many students do not have or use this knowledge (Flood, 1986).

Science Reading

Little research has been done on science reading, especially in elementary school (Weidler, 1984; White & Tisher, 1986). Although the research has been sparse, several conceptions of reading in science have been proposed. Wittrock (1981) applied a generative model of reading in which readers generate meaning by constructing relationships between their prior knowledge and the text to achieve science learning. Holliday (1988) modified Bransford's (1979) conception of reading to describe science reading.

[Insert Figure 1 About Here]

Holliday suggested that learners construct meaning through an interaction of critical tasks (the learner's goals), characteristics of the learner, and extracting information from the situation (text, charts, pictures, other people) while monitoring, strategically planning, and evaluating the process. The monitoring, strategic planning, and evaluation of the process are referred to as metacognition. Shymansky et al. (in press) proposed that "science reading involves the orchestration of concrete experience, prior knowledge, cognitive abilities, metacognitive operations and language to create understanding" (p. 4).

Unified Conception

Little evidence has been found that indicates elementary school teachers and secondary science teachers actually apply what is known abou: reading in their science instruction which utilizes textual material (Shymansky et al., in press; Yore, in press). Teachers generally value content reading instruction and content reading skills while not fully understanding the interactive-cons'ructive reading model and metacognition. Yore (1987) explored the potential of utilizing science text embedded in science inquiry and the mediating effects of general reading ability. He found that middle school students were afforded greater achievement equality when reading assignments followed experience and group discussion to invent a concept. Realizing the full potential of text involved skill development, supportive scaffolding, knowing when, why and how to use text material, accessing prior knowledge or providing prior experience.

Prior Knowledge

Prior knowledge is a critical factor in constructing meaning. Prior knowledge is knowledge and understanding constructed from previous experience. It is usually described as organized and stored in structures called schemata (Rumelhart, 1975). Prior knowledge includes conceptual knowledge (knowledge of concepts) and metacognitive knowledge (knowledge and control of understanding and the reading process).

Conceptual Knowledge. Readers use their prior knowledge to interpret, understand, and recall text (Bransford & Johnson, 1973; Mulcahy & Samuels, 1987;

Spiro, 1980b). Pearson and Johnson (1978) characterized the construction of meaning as building a bridge between new and prior knowledge. According to Holliday's model of science reading, the understanding students build is based on the students' prior conceptual knowledge in interaction with other factors.

The amount of direct experience with the concept to be understood has a tremendous influence on what readers bring to and take away from the science text (Osborne & Wittrock, 1983). Learners do not come to new learning with no background knowledge or experience. Long before students are formally taught, they construct conceptual knowledge based on past experiences, current experience, and their interactions. This prior conceptual knowledge is not a collection of isolated ideas; it is a conceptual framework that forms the student's view of the world. Driver and Erickson (1983) referred to student prior knowledge as invented ideas and suggested these conceptual frameworks are strongly held and resistant to change. Unfortunately these conceptual frameworks may be different than the desired reality. When new knowledge is compatible with prior knowledge, understanding is much easier than when new knowledge and existing schemata are not compatible (Lipson, 1984; Maria & MacGinitie, 1987). The amount of prior knowledge (Recht & Leslie, 1988) and the appropriateness of prior knowledge (Lipson, 1984) influence both understanding and the amount of information recalled from text. Although there appears to be agreement that prior conceptual knowledge plays an important role in comprehension, Shymansky et al. (in press) pointed out that "the role of prior knowledge or naive theories in science learning was not well accepted by elementary science teachers" (p. 16).

Metacognitive Knowledge. Readers' metacognitive knowledge about reading is an important dimension of prior knowledge (Jacobs & Paris, 1987). Cognition is an interactive-constructive process, and metacognition is a conscious reflection on this process. Recent reading research has focussed on the role of metacognition in the reading process. Metacognition involves the awareness and control of oneself and the reading process. Baker and Brown (1985) and Forrest-Pressley and Waller (1984) pointed out that beginning and poor readers lack metacognition associated with reading. Some children do not realize that they can use their prior knowledge in order to understand what they read. On the other hand, some readers tend to rely too heavily on prior knowledge when trying to understand text (Maria & MacGinitie, 1987).

Jacobs and Paris (1987) divided metacognition into two broad categories: self-appraisal and self-management of cognition. Self-appraisal of cognition includes knowledge about aspects of reading (declarative knowledge), knowledge about how to use specific procedures during reading (procedural knowledge), and knowledge about when and why to use these procedures (conditional knowledge). Self-management of cognition includes planning, monitoring, and evaluating cognition. Studies have focussed on knowledge students have about reading of narrative text (Meyers & Paris, 1978; Paris & Jacobs, 1984). The literature contains no studies about students' knowledge about science text and science reading.

Given the wide agreement among researchers that prior knowledge influences understanding of text, it is surprising how little research has been directed toward determining what the learner knows before instruction begins

(Erickson, 1977). Since students' conceptions and misconceptions influence the development of valid new concepts, teachers must know and consider the state of students' prior knowledge when designing instruction. Roe (1987) and Flood (1986) pointed out that one of teachers' major tasks in helping children comprehend text is to determine their background knowledge before asking them to read expository text. Engel Clough and Driver (1986) stated:

> From an educational perspective it has been argued that it may be necessary to take account of the ideas and beliefs that young people bring to their formal study of science if these ideas are to be successfully modified by instruction. (p. 473)

In determining how to assess prior knowledge, Holmes and Roser (1987) suggested the criteria of effectiveness and efficiency. Effectiveness refers to the amount of information obtained in relation to the time it takes to prepare the assessment , and efficiency refers to the relationship between the amount of information obtained in relation to the time it takes to give the assessment. Individual interviews are frequently considered to be the most effective assessment technique; however, they tend to be very time consuming to administer. Several researchers have suggested other approaches that may be more efficient and still have similar effectiveness, such as objective tests, concept maps, and word association (Jonassen, 1987; Lim, 1989; Roe, 1987).

This study attempted to compare the effectiveness of several assessment techniques and to construct a valid and reliable objective instrument. This preliminary report will concentrate on the assessment of metacognitive knowledge about science text and science reading. The assessment of conceptual knowledge about plants and science processes and the metacognitive knowledge of the scientific enterprise will be reported later.

Research Focus

The following foci guided the design, development, and conduct of this investigation.

1. Can the Jacobs-Paris approach be utilized to develop an instrument to assess self-appraisal of science text and science reading?
2. Which techniques of assessing self-appraisal of science text and science reading (structured interviews, structured objective tests, concept maps or word associations) provide acceptable levels of effectiveness while being efficient in a classroom setting?

Procedure

The following study was conducted in order to determine both the effectiveness and efficiency of several assessments designed to determine students' prior knowledge of science concepts, science reading, and science text. A combination of structured interviews (SI), structured tests (ST), concept maps (CM), and word associations (WA) was used to assess students' prior knowledge of science ideas, science reading, and science text and to judge the effectiveness and efficiency of alternative designs in relation to structured interviews.

Instruments

Structured Interviews (SI). The student and researcher sat together at a table in a quiet location free from distractions. Twelve questions related to the target topics (science ideas, science reading, science text) were asked in a nonjudgmental, supportive manner. Each student was asked a selection of six metacognitive questions (science reading and science text) and six consistent conceptual questions (plant kingdom and science processes). The metacognitive questions were generated to reflect the self-appraisal of an efficient, successful science reader (Jacobs & Paris, 1987; Yore & Denning, 1989). Six different interview protocols were utilized. Interviews lasted from 9-13 minutes and were tape recorded.

The questions were developed to parallel the metacognitive and conceptual dimensions reflected in the requisite knowledge about science text and science reading, and the concepts and processes involved with the study of plants. Some questions related to topics and had similar form to questions used in the structured test to allow direct comparison. Other questions considered topics or processes not included in the structured tests but were included because they utilized the full potential of the interview technique.

The interviewer probed for rationales to responses and clarified vague or uncertain responses. The interviewer avoided prompting the students, but efforts were taken to insure that the students' metacognitive and conceptual knowledge on specific issues was fully assessed. The six structured interview protocols are provided in Appendix A.

Structured Tests (ST). Students were given a test of 30 multiple choice and shoi' response items (14 conceptual, 16 metacognitive). Two conceptual items consisted of two-parts. The tests did not have a time limit and took the students from 10-33 minutes to complete. There were two forms of the test with common conceptual items and unique metacognitive items.

The conceptual test items were selected from two forms of a test on plants associated with a current science textbook series. The decision to utilize the prepared test items was based on the decision to use the specific science series textual materials in future research.

The metacognitive test items, utilizing a revised multiple choice format with an open response option, were developed to reflect the what, how, why, and when dimensions of science reading and science text (Jacobs & Paris, 1987; Meyers & Paris, 1978; Paris, Cross & Lipson, 1984; Paris & Jacobs, 1984). Items to assess declarative, procedural, and conditional knowledge related to specific factors regarding science text and science reading were developed from the desired image of an efficient, successful reader of science materials (Yore & Denning, 1989). The pool items were randomly assigned to two forms utilizing a stratified approach. Each form assessed some aspect of metacognitive knowledge of each dimension identified. Neither form assessed all factors or all three aspects of self-appraisal of a given factor in the desired image. Form A and Form B of the structured test are provided in Appendix B.

Concepts Maps (CM). Students constructed two concept maps, one of a science topic and one of a science reading. The assessment technique included a brief review of concept mapping with students utilizing an example concept from language arts. Next, students were provided two sheets of paper with the target concept (science reading and plant kingdom) clearly indicated on the center of the page. The concept maps took from 8-20 minutes to complete. The response sheets for the concept maps are provided in Appendix C.

Word Associations (WA). Students were given a list of repeated topics and asked to write words they believed were associated with the target topic on the line provided. Students were encouraged not to knowingly repeat themselves. The specific target topics were science reading, science text, and plant kingdom. The word associations took between 10-12 minutes to complete. The response sheets for the word associations are provided in Appendix D.

Sample

The study was conducted in four elementary schools in a small city in the interior of British Columbia, Canada. The schools represented a wide range of socio-economic areas, rural/urban setting, and school and class sizes. The sample for the study included 83 grade five students (n = 24, 21, 23, 15). The gender distribution was 40 males and 43 females. The average age of the students was 11 years 3 months, and the age range was 9 years 11 months to 12 years 5 months. All of the students spoke English as their first language.

The school district was well known to the research team. It had a well-developed language arts program and instructional program to enhance thinking. The science program utilized a traditional textbook series enhanced with hands-on experiences. The selected schools represented the full range of educational programs and student population in the school district.

Data Collection

The data collector was a knowledgeable, experienced teacher and former consultant in the school district. The study was carried out on four consecutive school days in early June. The assessments were administered on one day in each school. The four assessment tasks were administered in the same sequence and general time frame at each school. The sequence for the tests was ST, SI, and WA or CM. There was a minimum of 60 minutes between each assessment task with a physical activity to reduce transfer, and no science or reading instruction was provided until all tasks were completed. Students in each class were randomly assigned to ST Form A or Form B. They were again randomly assigned to WA or CM. Six students were randomly selected to represent a stratified sample of above average, average or below average male and female readers from each class. The students were interviewed in an order determined by random assignment. The specific form of the SI protocol was determined by random assignment.

Scoring

Scoring for the metacognitive items of the structured interview was based on a scale developed by Jacobs and Paris (1987). Responses were scored 0 if they indicated no knowledge or incorrect knowledge about science text and science reading; responses were scored 1 if they contained partial, vague or surface knowledge; responses were scored 2 if they contained precise, comprehensive or in-depth knowledge. The open response option in the structured test allowed students to write in their own response if none of the responses provided seemed appropriate. These responses were scored using the same criteria as those used for the predetermined responses. Form A or Form B composite scores were determined by the sum of the 16 individual item scores. The maximum composite score on Forms A and B was 32.

The structured interviews' responses were scored utilizing the same criteria and 0, 1, 2 scale for individual items as used on the ST responses. The total composite score for the SI was the sum of the scores on individual items contained in the specific protocol used. Composite scores are only meaningful for comparison amongst the four students exposed to the same protocol, otherwise they simply indicate a global metacognitive assessment on a 0-12 scale.

Word Associations were scored utilizing the same criteria and procedure for the open responses in the ST and SI. Each association was judged regarding its validity and the degree of understanding it conveyed. If several words were examples of one proposition or concept, they were grouped together and assigned a score based on the criteria for open responses in ST and SI. The scoring procedure for the WA is illustrated by the following science text example:

Science Text: Part of a book

Science Text: Table of Contents

Science Text: Chapters

Science Text: Glossary

Science Text: Index

Parts of a book (scored as 1) followed by a list of table of contents, chapters, glossary, and index (clustered and scored as 1). The composite score for the WA was determined by summing the points awarded each association provided. The composite score indicated a global metacognitive assessment of the target idea.

Concept Maps were scored according to established examples, propositions, hierarchy, and cross links criteria (Novak & Gowin, 1984, p. 35). The specific scoring criteria were:

1. *Propositions.* The valid meaning relationship between two concepts indicated by the connecting line and linking word(s) (score 1 point each).
2. *Hierarchy.* Subordinate valid concepts are more specific and less general than the concept drawn above it in the context of the material being mapped (score 5 points for each level of the hierarchy).
3. *Cross Links.* Meaningful, significant and valid connections between one segment of the concept hierarchy and another segment (score 10 points for each cross line that is both valid and significant or 2 points for each cross link that is valid but does not illustrate a synthesis between sets of related concepts or propositions).
4. *Examples.* Specific events or objects that are valid instances of those designated by the concept label (score 1 point each).

The composite score of the CM was determined by the total points awarded for propositions, hierarchy, cross links, and examples. The composite score indicated a global metacognitive assessment of the target concept mapped.

<u>Analysis of Data</u>

The analysis of data involved the validation of the instruments, establishing measures of internal consistency, and the generation of descriptive statistics for the sample assessed. Validity was explored in three ways: face validity, construct validity, and factor analysis. A fourth method of structural equation modeling is not complete at this time. Reliability was explored utilizing inter-item correlations, item-total score correlations, and a measure of internal consistency. The results of student performance are reported in percent frequency distribution, means, and standard deviations for individual items and total scores.

Validity

Face validity was engineered into the development by utilizing accepted constructs as the foundation for the instruments. The desired image of an efficient, successful reader of science materials was well grounded in the reading and science education research literature (Yore & Denning, 1989). The 20 factors of the desired image clearly describe many of the critical attributes of the ideal science reader as envisioned at this time. The blueprint of the ideal science reader was further clarified by expanding each of the 20 factors utilizing the self-appraisal dimension of metacognition to specify declarative, procedural and conditional knowledge (Jacobs & Paris, 1987). The blueprint became a 20 x 3 matrix that served as the contingency table for designing the assessment instruments.

The assessment strategy of the ideal science reader was based on established data collection techniques. The structured interview protocols sampled critical cells in the 20 x 3 matrix. It was believed that the rich nature of the information produced by the interview format (six strategic questions for each protocol and the six alternative protocols) would allow assessment of target factors and, considered in combination, would provide a reasonable global assessment of metacognitive knowledge about science reading and science text. A similar rationale was used to generate a pool of 31 objective items. Two stratified random samples of 16 items (one critical item was common to both forms) allowed data to be collected on many factors of the ideal science reader by each form of the structured test. Not all factors by categories of self-appraisal were assessed. The concept map and the word association instruments were designed to provide global assessments of metacognitive knowledge about science reading and science text.

Construct validity was partially explored by correlating the data collected by each method. The structured interview data were identified as the reference construct. The quantitative data on individual items were correlated with data from similar items on the structured test. The total scores on the interview were correlated with the equivalent combined scores of items from the structured test. The total metacognitive scores from the structured interview, the total score from the structured test, the global scores from the concept map, and the global scores from the word association were correlated to provide global indications that the instruments were assessing similar constructs.

[Insert Table 1 About Here]

The small but positive correlations between the interview data and the structured test item data and the structured test sub-scores were promising. Although only a very small amount of common variance was contributed by the shared assessment, improved item selection, item revision and combining the two forms into a single structured test may improve the construct validity of the structured test. The negative correlation between the SI data and Form B is problematic. The concept map and the word association require further consideration to explain the surprising correlation values discovered.

Principle components from rotated factor analyses were used to explore whether the structured test items clustered about dimensions of the ideal science reader. Table 2 indicates the principle components of Form A and Form B. The principle components revealed did not cluster exclusively within the categories of self-appraisal or along the factors of the ideal science reader. Several of the principle components could be labeled with a meaningful unifying concept. These results may be due to the small number of items and the small homogenous samples used.

[Insert Table 2 About Here]

Structural equation modeling is planned to explore the construct valid further. LISREL 6 will be used to determine if the hypothesized constructs were assessed by the items in the structured tests and to determine if items designed to assess a specific construct converge on that construct.

Reliability

Form A and Form B were the only data investigated for reliability. Inter-item correlations of items measuring the same factor of the ideal science reader or the same category of self-appraisal were considered. The majority of the item clusters reveal positive but small correlations indicating that these target items were associated as intended.

The item-total score correlations were used to assess the contributions made by each item to the total assessment. The correlations reveal that all items were positively associated with the total score of the structured test. Ten of the 16 items of Form A and 8 of the 16 items of Form B were significantly correlated with the specific total score.

The Alpha measures of internal consistency were low (Form A = 0.44 and Form B = 0.26). These low measures indicate that some individual items need revision and the number of items in the test should be increased. Preliminary exploration of excluding 3 items from Form A and 6 items from Form B raised the internal consistencies of the remaining test items to 0.50 and 0.40.

In summary, the structured tests appear to be an assessment technique that is efficient and has reasonable effectiveness. The concept map technique is promising, but familiarity with the process must be assured before using it as an assessment technique. The word association technique used needs further refinements. The structured interview and performance-based assessment still appear to be the most effective assessment techniques, but their efficiencies are low.

Results

The results of this study must be viewed in the light of the validity and reliability reported earlier. Furthermore, the sample represented a school district that has spent considerable effort on enhancing students' thinking and reading albeit narrative text was emphasized. Nevertheless the results reported may provide insights for further research or sharpened focus of future enquiries.

Interview Results. The 24 interviews indicated that the Grade 5 students:

1. knew that pictures, diagrams, charts and definitions help them to understand what they are reading,
2. were aware of different aspects of text structure,
3. knew that visual imagery and reflection were used in

order to understand what was read, and

4. knew that understanding is the main goal of reading.

Generally the students knew that they interact with text and other information sources in order to construct meaning. In addition many of them knew how, when and why to interact with text and other sources in constructing meaning from text. Eighty-five percent of the 140 valid responses indicated that the students had appropriate declarative, procedural and conditional knowledge about science text and science reading. Fifteen percent of the responses indicated students had inappropriate, incorrect or no knowledge about science text or science reading.

The number of responses indicating knowledge about science text and knowledge about science reading were similar, 84% and 86%, respectively. An examination of each category of self-appraisal indicated that 89% of the responses designed to elicit conditional knowledge, 84% for questions of procedural knowledge, and 83% for questions of declarative knowledge were scored 1 or 2.

Although there were only four responses for each question, the responses for individual questions or groups of questions merit consideration. Students who responded to questions about science text, what it represents and its purpose and value, indicated that text represents ideas and the words help the readers to understand. Some students realized that science text was not infallible and difficulties experienced with text could be due to text and not just the reader. Most students realized that some parts of a paragraph were more important than other parts and why, and that sentences were arranged in order depending on whether the paragraph outlined directions or had a main idea and supporting details.

Unfortunately students did not realize that since text has different structures it should be read differently. Students knew that adjuncts such as pictures, graphs and diagrams were useful as an aid to understanding and recall but were not sure when to refer to these aids.

Students who responded to questions related to the goal of reading knew it was important to understand, knew how they knew when they did not understand and knew they should think about what they were reading. They also knew they should check to see if what they were reading made sense but did not know when to do so. Students knew that the purpose of self-questioning, re-reading, looking ahead and visualization was to facilitate understanding of text. They also knew that teachers, other texts, and other students could help them to understand. Although they knew they could understand text better with prior knowledge of the topic, not all students referred to prior knowledge as a source to aid in understanding. Students saw ability to understand as a characteristic of a good reader but only one student out of four equated application of strategies with being a good reader. Students suggested a variety of ways for decoding a word or understanding a sentence. These included use of context, re-reading, reading ahead, and consulting with other students and the teacher. Only one student mentioned "sound it out". Although students perceived a difference between simply reading and reading to remember, not all of them suggested writing information down as a way to remember. One student suggested making a tape and playing it at night. Although students knew why and when to skim text, and had a fairly good notion of how to skim, they had very little knowledge of how to summarize or find the main idea.

Students appeared to have no knowledge of first determining a purpose for reading and then proceeding based on the demands of the task. But, they seemed to know what to do and how and when and why to do it after they started reading.

Structured Tests. The descriptive results for all assessment techniques and individual items are reported in Table 3. An inspection of the combined results for Form A and Form B indicates that the forms were not equally difficult. Performance on individual items revealed three general categories of results: high success (≥ 80% scoring 2, <10% scoring 0), average success (≥80% scoring 2 or 1, <20% scoring 0) and low success (<50% scoring 2, >30% scoring 0).

[Insert Table 3 About Here]

Results from Form A indicated that high success was noted on items 15, 16, 19, 21, 22 and 28. Low success was noted on items 29 and 30. Results from Form B indicated that high success was achieved on item 23 and that low succes was noted on items 21, 23, 24 and 30.

The central themes amongst the high success items consider the purpose of reading (A15), text features (A16, A22 and B23), prior knowledge (A19), and strategies (A21 and A28). The central themes amongst the low success items were text features (B21 and B24), reading to remember (A30 and B30), and strategies (A29 and B22). Many similarities to the interview results were found regarding strategic planning, summarizing and text structure.

Word Association and Concept Maps. The word association and concept map approaches provided some interesting global data, but to achieve consistency of scoring took a great deal of time. The final score produced was a global assessment and did not provide much more information than an intuitive scoring procedure. In both procedures the students appeared to simply brainstorm their responses without considering relationships between the responses. It is difficult to determine if the results reflect: students' lack of organization of their knowledge of science text and science reading; their perception that science text and science reading are the same concept; lack of familiarity with the CM and WA procedure; or lack of familiarity with these particular formats. Further consideration is planned, but the two assessments produced similar responses.

Implications

This preliminary study revealed that assessing readers' knowledge about science reading and science text will be a difficult process to bring the assessment techniques to psychometric standards of validity and reliability. The added issues of effectiveness and efficiency compound the problem. The solution will need to consider two levels of acceptance regarding classroom application and research applications. Each of the techniques described in this study has reasonable validity to identify readers' strengths and weaknesses. Each technique provided information to help guide general instruction, but none provided the precision necessary to make critical instructional decisions or to be used in precise research studies.

Future research and validation studies will need to revisit the desired image of a science reader, the conception of science text, and the conception of metacognition. The desired image of a science reader relied heavily on the general reading research and recent research results will help clarify the image. The conception of science text was based on studies from the 1970s; these studies and recent reports do not fully agree on the nature of science text. Therefore the new results must be reflected in the assessment blueprint. The original conception of declarative, procedural and conditional knowledge about science reading and science text contained an assumption of hierarchy that was not confirmed by the grade 5 interviews. The fuzzy aspects of metacognition require clarification regarding automaticity, application range, affective dimensions, and other issues.

The structural equation modeling (LISREL 6) may provide additional insights into the item-construct alignment. The fitting of various models and data may help clarify any causal relationships. The structural maps will help sharpen the design of items and the selection of the items. The combination of traditional test design procedures, structural equation modeling and construct clarification will likely lead to more effective and efficient assessment techniques.

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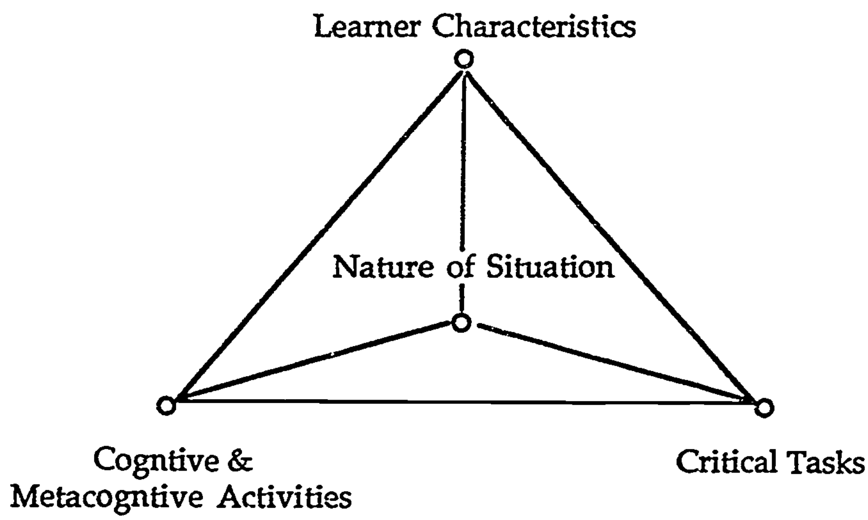

Figure 1: Tetrahedral Interactive Model (Holliday, 1988)

Table 1: Correlations Between Assessment Techniques and Specific Components

Instrument		ST Items	ST sub-score	ST A	ST B	ST A/B	CM	WA total
	r	0.16	0.21	0.07	-0.21	0.12	0.07	-0.30
SI	p	0.04	0.17	0.41	0.26	0.30	0.42	0.16
	n	128	24	12	12	24	11	13
	r						0.06	-0.01
ST A	p						0.39	0.48
	n						21	20
	r						0.48	0.52
ST B	p						0.02	0.01
	n						18	23

Table 2: Principle Compor.ents Resulting From the Rotated Factor Analyses of the Structured Test Items (Loading Value)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Form A	27 (.718)	19 (.827)	23 (.793)	30 (.840)	28 (.776)	26 (.803)	15 (.904)
	17 (.690)	21 (.752)	29 (.470)		25 (.525)	20 (.659)	
	18 (.679)	16 (.705)					
	24 (.639)						
	22 (.352)						
Form B	26 (.817)	23 (.813)	16 (.921)	21 (.828)	28 (.866)	15 (.929)	22 (.927)
	30 (.686)	25 (.746)	17 (.551)	19 (.555)			20 (.375)
	29 (.580)		18 (.421)				24 (.305)
							27 (.296)

Table 3: Descriptive Statistics for Specific Assessment Techniques and Items

	Full Value (%)	Partial Value (%)	No Value (%)	X	SD
SI (n=24)	-	-	-	8.67	1.93
ST					
Form A (n=42)	-	-	-	25.41	3.28
Item 15 (n=42)	40.5	9.5	0	1.91	.30
16 (n=42)	92.9	7.1	0	1.93	.26
17 (n=42)	73.8	19.0	7.1	1.67	.61
18 (n=42)	83.3	4.8	11.9	1.71	.67
19 (n=42)	90.5	7.1	2.4	1.88	.40
20 (n=42)	71.4	26.2	2.4	1.69	.52
21 (n=42)	85.7	9.5	4.8	1.81	.51
22 (n=42)	85.7	0	14.3	1.71	.71
23 (n=42)	35.7	50.0	14.3	1.21	.68
24 (n=42)	66.7	11.9	21.4	1.45	.83
25 (n=42)	35.7	57.1	7.1	1.29	.60
26 (n=42)	81.0	7.1	11.9	1.69	.68
27 (n=42)	83.3	4.8	11.9	1.71	.67
28 (n=42)	85.7	4.8	9.5	1.76	.62
29 (n=42)	33.3	23.8	42.9	.91	.88
30 (n=42)	40.5	26.2	33.3	1.07	.87
Form B (n=40)	-	-	-	20.56	3.49
Item 15 (n=40)	55.0	45.0	0	1.55	.50
16 (n=40)	57.5	30.0	12.5	1.45	.71
17 (n=40)	57.5	30.0	12.5	1.45	.71
18 (n=41)	24.4	61.0	14.6	1.10	.63
19 (n=41)	39.0	41.5	19.5	2.20	.75
20 (n=41)	58.5	24.4	17.1	1.42	.77
21 (n=41)	19.5	7.3	73.2	.46	.81
22 (n=41)	46.3	4.9	48.8	.98	.99
23 (n=41)	80.5	12.2	7.3	1.73	.59
24 (n=41)	24.4	26.8	48.8	.76	.83
25 (n=41)	75.6	17.1	7.3	1.68	.61
26 (n=41)	43.9	41.5	14.6	1.29	.72
27 (n=41)	58.5	34.1	7.3	1.51	.64
28 (n=41)	68.3	22.0	9.8	1.59	.67
29 (n=41)	58.5	22.0	19.5	1.39	.80
30 (n=41)	51.2	9.8	39.0	1.12	95
CM (n=39)	-	-	-	10.39	6.17
WA total (n=44)	-	-	-	11.23	6.80
WA Science Reading (n=44)	-	-	-	5.46	3.88
WA Science Text (n=44)	-	-	-	5.77	4.06

Appendix A

The Six Protocols for the
Structured Interviews
of Self-Appraisal
of Science Reading and Science Text

Structured Interviews

Protocol 1

1. What is the main goal of reading?
2. Why do you use the pictures, diagrams and definitions on a page in your science text?
3. Where do you get the information to help you make sense of your science text?
4. How do you skim a paragraph?
5. What topic in science would you find easiest to understand? Why?
6. Is it important to see if what you're reading makes sense? When should you do this?

Protocol 2

1. Are there things on the page of your science text that help you to understand what you are reading? What are they?
2. Should you ask yourself questions while you are reading your science text? Why?
3. Is there some part of a paragraph that is more important than the rest of the paragraph? What is it? Why is it important?
4. Should you read all paragraphs the same way? Why?
5. Should you go back and read something again? When?
6. How do you know when you don't understand what you have read?

Protocol 3

1. What could you do if you didn't understand what a sentence was about?
2. Do you ever make pictures in your head of what you are reading? Why?
3. What makes someone a good reader in science?
4. Do you ever look ahead in your science text? Why?
5. Is there something you should do before you start reading in your science text? What is it?
6. If you are reading a science text to study for a test what could you do to remember the information?

Protocol 4

1. Should you believe everything you read in your science text? Why?

2. How could you figure out a word in your science text that you didn't know?

3. Are words in a science text just words? What is important about them?

4. When would you skim a paragraph?

5. Are there times when you don't understand what you read in your science text? What would you say is the reason you don't understand?

6. When/How do you use the pictures, diagrams and definitions on a page in your science text?

Protocol 5

1. Is there some part of a paragraph that is more important than the rest of the paragraph? What is it? Why?

2. How do you summarize what you have read?

3. Are the sentences in a paragraph arranged in any order? How?

4. Some words in science texts seem to go together. If you saw the word 'if' what word would you expect to see later?

5. If you are reading a science text what could you do to remember the information?

6. Should you think about what you're reading? Why? When?

Protocol 6

1. Do you do anything before you start reading your science text? What?

2. What makes someone a good reader in science?

3. What could you do to help you understand what you are reading?

4. If a section in your textbook describes a problem what do you expect by the end of the section?

5. Is there a difference between reading and reading to remember? What is the difference?

6. How do you find the important (main) idea in a paragraph in your science text?

Appendix B

Form A and Form B
of Structured Tests
of Self-Appraisal
of Science Reading and Science Text

Form A

Name: ______________________

INTRODUCTION

This test is to help me to understand what you know about the plant kingdom, science textbooks and science reading. You will not be graded on this test, but you are taking part in a scientific study so do your best! Read the directions for each part before you start the questions.

PART II Science Textbooks and Science Reading

Read each question carefully and select the answer (circle letter) that best answers the question or write your own answer to the question in the space provided.

15. The main goal of reading science text is

a. to say all the words

b. to understand what it's about

c. to read quickly without making mistakes

d. ______________________

16. You refer to the pictures, diagrams and definitions on a page in your science text because

a. they help you to remember and understand

b. you won't need to read the words

c. they are interesting

d. ______________________

17. The information that you need to make sense of science text is

a. only in the text

b. in the text and in your head

c. in the teacher's head

d. ______________________

18. Skimming is

    a. reading all the short words and not the long ones

    b. something poor readers do

    c. a quick way to find out what the text is about

    d. ______________________________

19. Topics in science are easier to understand

    a. when you know something about the topic

    b. when the printing on the page is large

    c. when you have a comfortable place to sit

    d. ______________________________

20. Things on a page of your science text that are there to help you understand the words are

    a. page numbers

    b. pictures and diagrams

    c. sentences and paragraphs

    d. ______________________________

21. If you were reading science text you would ask yourself questions and think about what you were reading

    a. because it is a good thing to do

    b. to make sure that you knew all the words

    c. to see if you understood what you were reading

    d. ______________________________

22. The first sentence in a paragraph

    a. is no more important than any other sentence

    b. starts the paragraph

    c. frequently tells you what the paragraph is about

    d. ______________________________

23. Sentences in a paragraph are put together in different ways. Some describe, some are in order of happening and some compare and contrast ideas. Good readers

    a. read all paragraphs the same way

    b. read paragraphs differently

    c. read them all quickly

    d. ______________________________

24. Good readers go back and read things over again because

    a. it's a good idea

    b. they forget some words

    c. they didn't understand what they had read

    d. ______________________________

25. If you don't know what a whole sentence means you should

    a. read it again

    b. sound out all the words

    c. think about the other sentences in the paragraph

    d. ______________________________

26. Making organized mental pictures of what you read is useful because

    a. you won't need to write it down

    b. it helps you to remember it

    c. it makes the text more interesting

    d. ______________________________

27. Someone is a good reader in science if they

    a. read quickly

    b. like reading

    c. do things to help themselves understand

    d. ______________________________

28. Looking ahead in your science text is a good idea for

    a. getting finished your reading faster

    b. skipping over hard parts

    c. checking out your guesses

    d. ______________________________

29. Before I start to read

    a. I choose a comfortable place to read

    b. I stop and think about why I am reading

    c. I don't make plans, I just start reading

    d. ______________________________

30. When I am reading my science text to study for a test the most helpful thing for me to do is

    a. Outline what I have read

    b. write down everything I have read

    c. say all the words over and over

    d. ______________________________

Form B Name: ______________________________

INTRODUCTION

This test is to help me to understand what you know about the plant kingdom, science textbooks and science reading. You will not be graded on this test, but you are taking part in a scientific study so do your best! Read the directions for each part before you start the questions.

PART II Science Textbooks and Science Reading

Read each question carefully and select the answer (circle letter) that best answers the question or write your own answer to the question in the space provided.

15. Text in science books is

    a. never true

    b. someone's view of what is true

    c. always true

    d. ______________________________

16. When you come to a word and you don't know what it means you should

    a. ask someone else

    b. use the words around it to figure it out

    c. go on to the next word

    d. ______________________________

17. The words in your science text are

    a. for you to pay attention to

    b. labels for ideas and experiences

    c. what the author guesses to be true

    d. ______________________________

18. You use skimming, key words, titles and headings

    a. when the text is difficult to read

    b. when you want to read quickly

    c. when you want an overview of the text

    d. ______________________________

19. If you don't understand what you have read it is

    a. because science texts are sometimes not well written

    b. always your fault

    c. always because you didn't use the right reading skills

    d. ______________________________

20. You use the pictures, graphs and diagrams on a page by

    a. looking at them when your teacher tells you to

    b. looking at them when you have finished the chapter

    c. looking at them when you need to

    d. ______________________________

21. The parts of a paragraph that are most important are

    a. the first and last sentences

    b. the middle sentences

    c. all the sentences

    d. ______________________________

22. To summarize information in science text you

    a. tell the important ideas

    b. tell all the facts

    c. tell the last sentence in the section

    d. ______________________________

23. The sentences in a paragraph are

    a. not arranged in any special order

    b. all arranged in the same way

    c. arranged in certain orders

    d. ______________________________

24. When you are reading science and you see the word "if", what do you expect later?

    a. a "then"

    b. a "maybe"

    c. nothing

    d. ______________________________

25. If you are reading your science text and you want to remember the information you should

    a. write it down in your own words

    b. say every word over and over

    c. think about remembering it

    d. ______________________________

26. Before you read your science text it is important to

    a. think about what you already know about the topic

    b. find a comfortable place to read

    c. make sure you can read all the words

    d. ______________________________

27. Someone is a good reader in science if they

    a. read quickly

    b. like reading

    c. do things to help themselves understand

    d. ______________________________

28. To understand what you are reading you should

    a. ask yourself questions about the important ideas

    b. see if you know all the words

    c. keep reading

    d. ______________________________

29. When a section in your science textbook describes a problem, what do you expect later?

    a. another problem

    b. the cause of the problem

    c. a solution to the problem

    d. ______________________________

30. Is there a difference between reading and reading to remember?

    a. just reading is harder because you have to sound out all the words

    b. just reading is the same as reading to remember

    c. reading to remember is harder because you have to make notes as you read

    d. ______________________________

Appendix C

Concept Map
for
Science Reading

Please draw a mind map of "Science Reading"

SCIENCE READING

Appendix D

Word Associations
for Science Textbook and Science Reading

Words and Ideas That Go Together

Write down as many words or ideas as you can think of to go with "Science Textbooks".

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

Science Textbooks ______________________________

(Use the back of this sheet for other words or ideas)

Words and Ideas That Go Together

Write down as many words or ideas as you can think of to go with "Science Reading".

Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

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Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

Science Reading ______________________________

(Use the back of this sheet for other words or ideas)