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ABSTRACT

Reading science text is not simply a process of translating printed symbols into meaning; it involves the interaction of the reader's prior knowledge, beliefs, concurrent experience, and the text in a sociocultural context to construct new meaning and understanding. The purposes of this study were to: explore the associations between metacognition (awareness and self-management) and science reading comprehension; investigate the effects of teaching science reading strategies on science reading metacognitive awareness, science reading metacognitive self-management, and science reading comprehension; and explore differential effects of science reading instruction on science reading metacognitive awareness, science reading metacognitive self-management, and science reading comprehension for specific reading ability and gender groups. The investigation used a single-group pretest/posttest case study design to capture the ecological validity of an intact classroom of 27 grade 7 students and their teacher. Results indicate significant correlations between metacognitive awareness and comprehension task success and a positive association between metacognitive self-management and comprehension task success and that a differential learning effect had taken place with lower ability readers and males gaining more from the instructional treatment. The results illustrate the impact that explicit instruction can have on science reading ability. Contains 55 references. (JRH)

Explicit Science Reading Instruction in Grade 7: Metacognitive Awareness, Metacognitive Self-Management and Science Reading Comprehension

Paper presented at the National Association for Research
in Science Teaching Annual Meeting
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INTRODUCTION

Reading science text is not simply a process of translating printed symbols into meaning; it involves the interaction of the reader's prior knowledge, beliefs, concurrent experience, and the text in a sociocultural context to construct new meaning and understanding (Yore & Shymansky, 1991). The interactive-constructive model of science reading acknowledges this relationship—meaning making, not meaning taking—as well as the importance of text-based reading strategies and the awareness and control of meaning-making (metacognition: thinking about your thinking as you are thinking to improve your thinking) that the reader must possess to be successful. Ruddell and Unrau (1994) stated that the reader, the text, the classroom context, and the teacher are interacting components of the reading process in schools. They clearly identified the metacognitive, topical and domain knowledge and beliefs required to comprehend text and for effective reading instruction (Figure 1).

Insert Figure 1 about here

It is widely believed that science reading comprehension and reading strategies could be enhanced by explicit comprehension instruction embedded in the normal science instruction by the regular classroom teacher (Glynn & Muth, 1994; Holliday, Yore & Alvermann, 1994; Simonsen & Singer, 1992). The specific format of the comprehension instruction and its potential transferability are not fully known. The effectiveness of explicit instruction in reading strategies and other metacognitive reading instruction may vary according to the grade level, the reading level, and the cognitive ability of the student. Yore, Craig and Maguire (1993) found that strategic awareness varies significantly and predictably between good and poor readers and also between females and males, but they found unexpected significant grade-level differences. They believed that the grade-level differences were due to inconsistent or lack of explicit science reading instruction in the upper middle school years. Metacognitive strategies instruction seems to be most effective for students in the middle grades, especially Grade 7 (Haller, Child & Walberg, 1988).

The purposes of this study were to explore the associations between metacognition (awareness and self-management) and science reading comprehension; to investigate the effects of teaching science reading strategies on science reading metacognitive awareness, science reading metacognitive self-management, and science reading comprehension; and to explore differential effects of science reading instruction on science reading metacognitive awareness, science reading metacognitive self-management, and science reading comprehension for specific reading ability and gender groups (Spence, 1994). Results of these inquiries may help clarify the fuzzy links between metacognition and cognition, help inform science reading instruction, and help provide insights into enhancing teachers' understanding of science reading and science reading instruction.

BACKGROUND

Science text and science reading have been criticized; but both continue to be frequently used in elementary, middle, and high school classrooms. Unfortunately, the criticisms have stifled consideration of science text, science reading, and science reading instruction in many teacher education and professional development programs. The result of this disregard has partially contributed to teachers' poor understanding of science reading theory, too many ill-informed instructional decisions, and too little explicit strategy and comprehension instruction being provided students with science reading difficulties (DiGisi & Willett, 1995; Gottfried & Kyle, 1992; Shymanksy, Yore, & Good, 1991; Yore, 1991).

Historically, the criticism of science reading was partially based on the perception that science reading was a passive, text-driven, meaning-taking process while science learning was perceived as an active, hands-on, meaning-constructing process. Actually, the science reading process is poorly understood. "[T]he scientist sits down with pencil and paper and slowly works through the article, making notes along the way. Unclear points are pondered over, references are looked up, numerical calculations are checked" (Mallow, 1991, pp. 329-331). The interactive and constructive natures of scientific reading are apparent as an expert accesses internal and external information sources and actively makes meaning of text. Novices likely face a much more demanding task as they access prior knowledge and work interactively in a sociocultural context to construct understanding from a science textbook.

Interactive-Constructive Model

Currently, the contemporary conceptions of reading closely parallel the constructivist perspectives of science learning. Commonalities of processing information from various sources do exist; but the differences in the interactive nature of primary, secondary, and tertiary information sources must be considered (Resnick, 1987). Hands-on activities respond to the learner's action, while most audio-visual and print materials do not respond to the learner's action. The interactive-constructive model considers both the similarities and differences in perception and processing of these information sources and how prior knowledge, task, concurrent experience, language, metacognition and context influence these situations (Yore & Shymansky, 1991).

Science reading involves accessing prior knowledge from long-term memory, interpretations from text and sensory information from the environment, and interactively constructing meaning of these data in working memory. Science reading appears, however, to involve much greater conceptual demands than most narrative text. Readers must have knowledge about the scientific enterprise, the concept under consideration, the scientific language, the patterns of argumentation, the canons of evidence, the science reading process, the science text, and the science reading strategies. Accessing this prior knowledge involves information retrieval strategies, while inputting sensory information involves science processes, decoding text involves bottom-up reading strategies, and interpreting verbal discourse involves interpersonal communication skills.

Inspection of almost any science textbook passage will clearly illustrate the complexity of constructing understandings from text. Closer analysis will reveal the concepts that are explicitly or implicitly addressed in the text. But some readers bring to the text a rich conceptual network and related experiences while other readers bring few related experiences and inaccurate prior knowledge to the task. The interactions with text, prior knowledge, concurrent experience, and context are required by the questions, examples, and inquiries embedded in the passage. The construction of understanding in the classroom is supported by a scaffolding of text structure (cause-effect, listing, description, problem-solution, compare-contrast), text features (graphs, diagrams, pictures, margin notes, bold print), socially shared activities (experiments, discussions, role plays, games, directed reading activities), and teacher guidance (questions, referrals, discussions, direct instruction).

The construction of meaning appears to be a generative process that occurs in short-term memory, which serves as a working interface between sensory input and long-term memory (Osborne & Wittrock, 1983). Pressley, Goodchild, Fleet, Zajchowski, and Evans (1989) stated:

> Information is assumed to be registered in sensory organs, with some filtering taking place at this level before it passes into short-term memory, that is, into consciousness....(where) information is lost rapidly unless it is processed. (p. 302)

Short-term memory, like a workbench, has limited capacity; and efficient information management, strategy application, and executive control are required for effective utilization of this limited memory (Britton, Glynn & Smith, 1985).

Readers make meaning by using top-down processes in which tentative mental models are constructed from the new information and tested against prior knowledge and socially shared standards. This process of negotiation and appropriation involves the dynamic reciprocals of internal hypothesizing and testing. The constructed meanings are stored in long-term memory by integrating these new ideas into existing knowledge structures or by reorganizing knowledge structures to accommodate the new ideas. Ruddell and Unrau (1994) stated:

> Knowledge use and control are at the heart of the knowledge-construction process through purpose setting, planning and organizing, and constructing meaning in the form of text representation. (p. 1022)

The construction of meaning must be orchestrated by the readers' metacognition—awareness and executive control—that may be automatic and transparent in unstressed situations but becomes overt and conscious in cognitively demanding situations (Garner, 1994; Jacobs & Paris, 1987). Jacobs and Paris (1987) suggested that metacognition is the conscious self-appraisal (awareness) of one's own knowledge of task, topic, and thinking and the conscious self-management (executive control) of the related cognitive processes (Figure 2). Using this interpretation of metacognition, self-appraisal becomes knowing **what** strategy, knowing **how** to perform the strategy, and knowing **when** and **why** to use the strategy. Self-management becomes the **planful** setting of purpose, accessing prior knowledge, selecting appropriate strategies, and outlining a heuristic; the continuous **monitoring** of progress by checking, self-questioning, and comparing; and the **adjusting** of action and effort by seeking external help, using a new heuristic, and selecting a different strategy. Thinking of metacognitive awareness and executive control in terms of three components helps clarify the image, but recent research has not been able to document their independent nature by means of factor analysis and linear structured modeling techniques (Schraw & Dennison, 1994; Yore, Craig & Maguire, 1993).

Insert Figure 2 about here

Science Reading, Science Text, and Science Reading Strategies

The limited research on science text, science reading, and science reading strategies has focussed on high school and university students and has revealed limited strategy use, expert-novice differences, domain specific influences, text structure and text features influences, conceptual change difficulties, and interpretative framework influences. Wandersee (1988) found that university students demonstrated limited science reading strategies when faced with comprehension failure, re-read was their single most common fix-up strategy, academic achievement was associated with the number of re-readings, and flexibility was apparent for different criterion tasks but not for different content texts.

Dee-Lucas and Larkin (1986, 1988a, 1988b) found that novice science students' judgments of importance was influenced by information type, focussing on facts, definitions, and numerical equations while expert science students' judgments emphasized conceptual information and overarching ideas. Ferguson-Hessler and de Jong (1990) found that good and poor science students were equally active while studying text and exhibited similar numbers but different study strategies when utilizing scientific text; however, good students were more astute in the application of these strategies and attended to procedural and conditional knowledge rather than simply declarative knowledge. Reif and Allen (1992) suggested the differences between expert and novice students reflect the type and form of scientific knowledge utilized to interpret and apply science concepts.

Alexander and Kulikowich (1994) identified ten assertions about learning from physics text based on a synthesis of earlier work. They stated:

- Limited topic or domain knowledge can have a significant negative impact on understanding physics text.
- Out-of-school knowledge may be an impediment to understanding physics text.

- Individual interest in physics seems linked to readers' knowledge.
- The bilingual character (mathematical/scientific and linguistics features) of physics texts may increase processing demands.
- Situational interest can direct readers' attention away from important scientific content.
- The perspective that individuals bring to the physics texts alters comprehension.
- Analogies included in scientific texts may not always facilitate comprehension.
- Instructional importance may exert greater impact on students' text processing than structural importance.
- Teachers' explanations can help or hinder students' learning from physics text.
- Technological advances can introduce greater complexity into the process of learning from physics text. (pp. 896-905)

The reader's knowledge about and usage of text structure (description, listing, compare/contrast, cause/effect, problem/solution) and text features (print signals, headings, graphs, tables, pictures, embedded questions, etc.) influence reading comprehension of science materials (Armbruster, Anderson & Ostertag, 1989; Cook & Mayer, 1988; Holliday & Benson, 1991; Holliday & McGuire, 1992; Loman & Mayer, 1983; Pizzini, Shepardson, & Abell, 1992). Spiegal and Barufaldi (1994) found that explicit text structure and graphic organizer instruction improved recall and retention of science information.

A meta-analysis of recent reading research that addressed students' misconceptions revealed that conceptual change involved more than engagement and refutation of the reader's misconception and that learning cycles, bridging analogies, and conceptual change approaches were most successful in remediating misconceptions (Guzzetti, Snyder, Glass & Gamas, 1993). Alvermann and Hynd (1989) found conceptual change physics text that engaged students' prior conceptions and addressed alternative interpretations did not significantly change the students' physics misconceptions. Hynd, McWhorter, Phares, and Suttles (1994) found that multiple experiences (demonstration, talk, and text) were needed to initiate conceptual conflict and to achieve conceptual change and that peer-group discussion could have a negative effect.

The belief system, orientation or interpretative framework that a reader brings to a science learning situation will influence the understanding constructed (Carey & Smith, 1993). Norris and Phillips (1994) found that good high school science students frequently ascribed greater truth to inferences reported in science articles than the authors likely intended. Craig and Yore (1995) found that 70% of middle school students interviewed ascribed greater authority to printed science ideas than to their own knowledge and concurrent experiences. These results may indicate that readers have inaccurate conceptions of science.

Desired Image of a Science Reader

The narrative reading research results, limited science reading research literature and analyses of science learning research, goals of science education, nature of the scientific enterprise, and science textual materials were synthesized to provide a desired image of an efficient, successful science reader (Yore & Craig, 1990; Yore & Denning, 1989). This model contained 21 clusters of bottom-up and top-down skills, knowledge about science reading, and conceptions of scientific text collected around specific heuristics. The skill clusters were judged to be strategies, "action plans, methods, or a series of maneuvers that reflect the characteristics and demands of the task" (Rivard & Yore, 1992, p. 9).

It may be more productive and accurate to think of the efficient, successful science reader in a holistic manner as a flexible, strategic person who is aware of and manages her/his science reading, use of science text and utilizes science reading strategies to construct understanding within a specific sociocultural context. This person:

- realizes that **science reading** is an interactive-constructive process involving the reader, the text, and the context and is designed to make meaning of print rather than take meaning from text by integrating prior knowledge, concurrent experience, and text-based information.
- has the abilities, self-confidence, and self-efficacy necessary for **science reading** as an assigned task and for personal pleasure.

- operates at the automatic-level when the **science reading** is proceeding successfully, but shifts to conscious, deliberate approaches when the reading comprehension is difficult or the task's demands dictate.
- realizes that science words are labels for ideas, science ideas are based on experiences, and **science text** is stored descriptions and explanations of ideas, events, or patterns.
- realizes that science is people's attempt to search out, describe and explain patterns of events in the universe, that **science text** is not an absolute truth, and that **science text** is a form of interpretation of ideas resulting from the scientific enterprise.
- evaluates **science text** for plausibility, completeness, and interconnectedness by verifying the textual message against prior knowledge, evidence, and observed reality and by assessing the logic and plausible reasoning of the text's patterns of argumentation.
- identifies purpose for science reading, accesses prior knowledge, plans heuristics, and selects appropriate **strategies**.
- uses specific knowledge retrieval **strategies** to access prior domain and topical knowledge from long-term memory.
- uses specific knowledge input **strategies** to access text-based information from print and visual adjuncts and to access information from the context.
- uses knowledge constructing **strategies** to integrate new information and established knowledge structures, to reorganize knowledge

structures to accommodate discrepant information, to negotiate understanding, and to establish importance.

- applies critical thinking **strategies** to assess validity of information and to verify constructed understanding.
- uses monitoring **strategies** to assess comprehension.
- uses **strategies** to regulate effort, actions, and approaches to fix-up comprehension failure as required.

Explicit Science Reading Instruction

Explicit science reading instruction has been unpopular since the 1960s science reform. Most support for this position has been from outside the science education community; but recently Project 2061's focus on science literacy with its habits-of-mind goals, including communication and critical response, has provided renewal momentum for reading to learn and writing to learn within the science education research community (AAAS, *Benchmarks*, 1993).

Science reading comprehension instruction needs to be explicit, embedded, long-term, and multi-faceted: domain knowledge, topic knowledge, science reading, science text, and specific science reading strategies. The instructional targets must focus on coordinated use of a limited number of powerful and diverse strategies. Pressley, El-Dinary, Gaskins, Scherder, Bergman, Almasi, and Brown (1992) stated:

> Teachers introduce only a few new strategies at a time, with introduction of new strategies extending over a long period of time. ...They encourage habitual reflection and planning before responding (p. 514).

Instruction must promote meaningful understanding of strategies, not a mechanistic use of strategies. Pressley, El-Dinary, et al. (1992) identified the need to document strategies instruction that reflected a contemporary view of reading and the realities of the actual classroom. Much strategy instruction research lacks ecological validity.

Instructional approaches must keep issues of potential treatment-learner interactions, domain-specific applications, and transferability central. It is generally accepted that some reading strategies are not equally applicable across all types of text and content domains. Comprehension instruction must attempt to maximize transfer of strategies beyond the classroom and instructional context to other appropriate applications (Pressley, El Dinary, et al., 1992). Furthermore, comprehension instruction must consider the importance of prior domain and topical knowledge required for effective strategy instruction. Older students, or those that have high ability in reading, may need less instruction than younger students or those with lower reading ability, to develop metacognitive awareness or to understand how strategies can be helpful in comprehending text.

Taken collectively, the results appear to suggest that explicit instruction may differentially impact younger, low prior knowledge, low reading ability, male students more than older, high prior knowledge, high reading ability, female students. Any consideration of metacognitive awareness must consider why and when as well as what and how. Furthermore, explicit instruction and metacognition must be limited to authentic assessments of science reading.

It is apparent that informed expectations need to guide the design of comprehension instruction and the interpretation of the results. Dole, Duffy, Roehler, and Pearson (1991) and Pressley, Johnson, Symons, McGoldrick, and Kurita (1989) identified several reading strategies that were critical, underdeveloped in readers, and responded to instruction:

- Assessing the importance of text-based information and prior knowledge.
- Generating questions to set purpose.
- Summarizing.
- Inferring meaning.
- Monitoring comprehension.
- Utilizing text structure.
- Reading and reasoning critically.
- Improving memory.
- Self-regulating to fix-up comprehension failures.
- Skimming, elaborating, and sequencing.

Since science text is unique and transfer of strategies is difficult, explicit science reading instruction should be embedded in the natural context of effective science instruction and commonly used science text. Pearson and Dole (1987) suggested that explicit comprehension instruction should: (1) establish a need-to-know, (2) model the desired outcome, (3) provide directed practice, (4) encourage strategy consolidation, (5) facilitate the transfer of ownership to the student, and (6) provide opportunities to apply the strategies in other situations. This approach differs from the traditional basal reader paradigm of teaching, practicing, and assessing. Instruction needs to be embedded in natural, authentic situations. The teacher does not talk about the skill or strategy but instead models or provides direct metacognitive explanation of what, how, why, and when a comprehension strategy ought to be used in the textual materials readily available in the classroom. The teacher gradually refocusses and decreases the supportive scaffolding. Students are not required to practise the new skill on their own. Instead, the teacher provides guided practice and has the students work in groups to discuss their strategic problem-solving options. Responsibility for and ownership of a strategy is gradually transferred to the students until they are able to complete the task on their own. It is at this time that the remaining teacher scaffolding is removed. Finally, the teacher does more than simply assess the students on the performance of the strategy: the students are asked to apply their strategies to new and different situations.

The explicit instructional model encourages students to monitor their use of strategies and their cognitive performance carefully. Students are taught to change tactics when a procedure is not producing the desired outcome. The hallmark of explicit instruction is the extensive, supervised practice and feedback given to the students. This study focussed on the following strategies: using surface text structure and organization; accessing prior knowledge, setting purpose, and monitoring comprehension; understanding word meaning through context; identifying main ideas; and summarizing text (Spence, 1994).

Surface Structure and Organization. The layout of the text, the titles of the sections, the diagrams, pictures and charts, and the questions posed in the text are surface features and organizational clues that aid readers' comprehension. These clues provide an outline of what the text was about and what some of the subtopics may be. Considerate science text provides consistent layout, logical topic development, and wealth of pictures, graphs, tables, and illustrations to enhance the meaning constructed from the printed message. Effective science text provides advance organization of units and chapters and generally provides concrete experience with a topic prior to most reading activities.

Accessing Prior Knowledge, Setting Purpose, and Monitoring Progress. Before starting to individually read text, readers need to access and organize what they already knew about the topic and establish a focus

(Ogle, 1989). The K-W-L chart acts as a dynamic learning guide with the first section being a listing of what the students know (K) about a topic before doing any reading. This section often includes misconceptions the students have acquired. In the next section the students list questions they want (W) answered or information they want to know. Much discussion occurs in completing these two sections of the chart, and the questions posed act as a compelling purpose for reading. In the third column the students keep a record of what was learned (L) from the total experience, including the reading. As the students read on, more questions are often added to the 'want to know' column.

The students need to consider the assigned reading task in terms of their specific reading goals; i.e., establishing the main idea or linking new information with already known information. With awareness of the goals in mind, the students must focus on the mental processes of planning, monitoring, checking, and revising their comprehension as they undertook the reading task.

<u>Using Context to Define Words</u>. Science text is composed of unique word labels for scientific concepts that are uncommon in non-science text, and these word meanings reflect specific situational context. Effective readers frequently make decisions about word meaning based on contextual clues provided in the word, sentence, and passage.

The use of prefixes, suffixes and root-words, the use of metaphors and analogies provided, the use of specific signal words and logical connectives, and the use of general text meaning are skills involved in the defining from context strategy. This strategy can be modelled and discussed as opportunities arise during authentic reading. The teacher thinks-aloud while modelling to clearly illustrate what component skills were used and what clues were available.

Identifying the Main Idea. Finding the main idea in science text often requires delineating supporting information, details, and examples. Often, a paragraph will not contain a specific topic sentence, which makes the task of finding the main idea particularly difficult for young readers. By learning to identify topic sentences in paragraphs containing them, inventing topic sentences if none exist, and finding main ideas in a variety of textual contexts, the students are better able to monitor their understanding of the text. Identifying main ideas involves using a variety of clues: titles, bold print, pictures, margin notes, in-text questions, and context.

While working in small groups, the students read a science text passage, construct the main ideas and verify their understanding with the other members of their group or the teacher. New concepts are added to the K-W-L charts, and new questions posed for later discussion with the class or the group.

Summarizing. A summary is defined as "a brief statement which contains the essential ideas of a longer passage or selection" (Harris & Hodges, 1981, p. 316). Summarizing is often confused with determining importance; however, it is a broader, synthesis activity for which determining importance is necessary but insufficient (Dole, et al., 1991). Ineffective readers encounter difficulty differentiating the key points when asked to summarize and often retell the entire passage (Yore & Shymansky, 1991). Explicit instruction on selecting important information while deleting unimportant information and condensing the material into a coherent and accurate representation of the original material has been shown to improve comprehension (Dole, et al., 1991).

Hare and Borchardt (1984) described a strategy that could be taught to students to help them write effective summaries. It contained two general steps in preparation for writing:

1. make sure you understand the text, and
2. look back and reread important parts.

It also contained two general steps to use following writing:

1. rethink the theme of each paragraph, and
2. check and double-check.

Four rules of summary writing are; collapse lists to one or two essential words, use topic sentences, edit out unnecessary detail, and collapse paragraphs to only important information.

Design

The investigation used a single-group pretest/post-test case study design to capture the ecological validity of an intact classroom of Grade 7 students and teacher. This design was used to monitor the implementation and the effects of explicit instruction on a heterogeneous group of students (Spence, 1994).

The pretest consisted of a survey and a science reading comprehension task. The survey consisted of two parts: one to assess the students' metacognitive awareness of science reading strategies (*Inventory of Science Reading Awareness*—ISRA, Yore, Craig, & Maguire, 1993) and a second part to assess the students' self-management of specific strategies (Holden, in progress). The content reading comprehension task was designed to assess the students' performance on answering questions based on a reading passage about a science topic unrelated to the planned instruction. Each student completed the same metacognitive survey and one of three parallel science reading comprehension tasks that utilized similar passages about three different planets in the solar system. The reading comprehension tasks were assigned randomly. The instructional treatment provided the students with explicit expository reading instruction embedded in the context of their normal guided inquiry science instruction using *Journeys in Science* (Collier, Macmillan, 1990) as the main textual resource. The effects were measured by re-administering the metacognitive survey and administering all three of the science reading comprehension tasks, one of which the students completed as a pretest.

Sample and Setting

One intact group of 29 Grade 7 students were the subjects of this study. The students were primarily randomly assigned to the teacher/researcher's class although students with histories of poor behavior were favored somewhat. During the school year two of the students moved away from the school and did not complete the study. Of the 27 students who did complete the study, 14 were male and 13 were female. Within this group there were wide variations in academic ability and social behaviors. Each child's reading ability was assessed according to past achievement in previous grades and according to the teacher/researcher's appraisal over the length of the school year. Eleven students were assessed as being below grade level reading ability, eleven were assessed as being at grade level, and five were assessed as being above grade level. Their ages ranged from 11 years 10 months to 13 years 5 months at the beginning of the study. The students in this group were part of a total group of 41 Grade 7 students in a K-7 elementary school of 430 students.

The school is situated in a suburban area and services military housing with a population that is largely transient; the students often spending only a few years in any one school. Average income in the area is lower middle class. Because it is typically the male parent that is the naval employee and usually assigned to a naval ship, there is often only the mother of the household at home to tend to the needs of the family and regulate such things as hours of play and homework times.

Instruments

The three outcome variables (metacognitive awareness, metacognitive self-management, and science reading comprehension) were measured using established approaches. Metacognitive awareness was measured by the Index of Science Reading Awareness (ISRA). Metacognitive self-management was measured by objective test based on the ISRA's design. Reading comprehension was measured using a traditional approach of reading a science passage and answering related comprehension questions.

Index of Science Reading Awareness. The ISRA is a 63 item multiple-choice with open response option based on the desired image of the efficient, successful science reader. The reliability and validity of the ISRA were explored by examining interview and test responses of 49 middle school students and by analyzing test responses of 532 middle school students (Yore, Craig & Maguire, 1993). Internal consistency of the ISRA of 0.88 and subtest of 0.51 to 0.82 were reported. Construct, concurrent, predictive, and structural validities were supportive of the desired image of an effective, efficient science reader and the ISRA and the three subtests (science reading, science text, and science reading strategies).

Science Reading Self-Management. The design features of the ISRA were extended for four science reading strategies: accessing prior knowledge, identifying and using text structure, finding main ideas, and writing summaries. Each strategy was assessed with a planning item, a monitoring item, and a regulating item (Jacobs & Paris, 1987). Holden (in progress) found reasonable internal consistency of the 12 item self-management test. Schraw and Dennison (1994) found that a set of items designed to measure self-management did not aggregate into three distinct components but rather was a unified cluster.

Science Reading Comprehension. Reading comprehension was measured using three passages taken from *The Atlas of the Solar System* (Yenne, 1987). Each passage contained information about a planet in the solar system: either Mars, Mercury, or Jupiter. The passages were very similar in content and structure but did not relate to the specific topics covered in the instructional treatment. The readability was considered to be well above Grade 7 level. Nine questions based on each passage were developed to test the reader's comprehension. The questions for each passage were designed to be similar in difficulty, but results indicated that one test was less difficult than the other two. Only 1 question of the 27 questions was text implicit in nature, an unaccounted irregularity; the other 26 were text explicit questions.

Instruction

Science classes basically followed the recommended text *Journeys in Science* (Collier, Macmillan, 1990), Unit 1, which explores the nature of science and scientific inquiry, Unit 2, which investigates properties of matter, and Unit 3, which examines the classification of living things and their characteristics and interactions. Most activities or experiments outlined in the text were carried out, most often before reading the text and often again after reading; and other resources such as videos and library books on related topics were frequently used in the classroom.

A typical lesson started with a class or group activity that would serve to motivate, provide problem focus, and begin to access and engage prior knowledge. The lesson would then move to a class or group discussion of observations or questions posed by students or teacher, and a K-W-L chart (Ogle, 1989) would be used in a whole-class activity to further access prior knowledge and help students set a purpose for reading the science text. The teacher would then review a reading strategy that was taught in a previous lesson or introduce a new reading strategy that applied to that day's reading. Part of the text might be read aloud by the teacher or a student, and the thinking processes involved in using the strategy would be modelled aloud and discussed. Students would then be given a quiet time for reading and investigation of the various materials. Some kind of reading strategy would be assigned, such as identifying the main ideas; and very often summaries of different forms were written individually or in pairs. The resulting products would be discussed as a group or class for accuracy and completeness. During this time of individual or small group reading and writing, there were many opportunities for the teacher to interact with individual students to provide a scaffolding of supervised practice and feedback. Finally, the class would end with group and class discussions about the reading and/or concepts investigated in a summative format that served to reorganize the students' knowledge of the topic and highlight the usefulness and conditional aspects of the reading strategies.

Results

The metacognitive survey items were scored on a 0-2 scale, "0" denoted no or incorrect understanding, "1" denoted surface understanding, and "2" denoted comprehensive, strategic understanding. The metacognitive awareness survey had a maximum score of 126, while the metacognitive self-management survey had a maximum score of 24. The nine science reading comprehension task questions were scored "0" (incorrect) or "1" (correct) producing a maximum score of 9. The posttest score for science reading comprehension is the average performance on the three passages.

Tables 1, 2, and 3 provide the descriptive statistics for the pretest and posttest scores for metacognitive awareness, metacognitive self-management, and science reading comprehension. The degree of association between metacognition and science reading comprehension was established using a correlation technique. The results indicated the following associations for pairs of the dependent variables: pretest awareness and comprehension 0.34 ($p \leq 0.10$), pretest self-management and comprehension 0.11 ($p > 0.10$), posttest awareness and comprehension 0.51 ($p \leq 0.01$), and posttest self-management and comprehension 0.36 ($p \leq$

0.10). The positive associations and the increased definition of the associations between pre-instruction and post-instruction results appear to support a theoretical causal relationship between metacognition and science reading comprehension.

Insert Tables 1-3 about here

Improvements between pretest and posttest measures of the dependent variables were explored using correlated t-tests (Table 4). Gains on all three variables for the total group were significant ($p \leq 0.001$). These results appear to indicate that Grade 7 students' metacognition and science reading comprehension can be improved over 22 weeks when explicit strategy instruction is part of the instructional program.

Insert Table 4 about here

Differential learning effects for various reading ability and gender groups were investigated using Analysis of Covariance (ANCOVA) since it was unlikely that 22 weeks of explicit instruction would completely address predicted differences established over six years of schooling. The series of ANCOVA's revealed a single significant main effect on posttest results (gender, self-management) when pretest differences were controlled (Tables 5-10). Generally, greater improvements were made by the low-ability readers than the high-ability readers on metacognitive awareness, metacognitive self-management, and science comprehension; and by the male readers than the female readers on metacognitive awareness and science reading comprehension. Only metacognitive self-management did not exhibit the differential effect anticipated for gender groups. The consistent pattern supports the effectiveness of explicit strategies as a method to improve science reading comprehension within the limitations of the experimental design.

Insert Tables 5-10 about here

Discussion

This study investigated the association of metacognition and reading comprehension, the effect of explicit instruction on metacognition and reading comprehension, the potential differential learning effect of instruction on less able readers, and the potential gender differences that may affect learning. Results of analyses of pretest and posttest scores on the metacognitive surveys and comprehension tasks indicate significant correlations between metacognitive awareness and comprehension task success and a positive association between metacognitive self-management and comprehension task success. These associations became more well defined over the 22 weeks of instruction. The gains made between the pretests and posttests on the metacognitive surveys and the comprehension tasks indicate that the 22 weeks of instruction that included science instruction and explicit instruction on metacognitive reading strategies had an effect on reading comprehension performance. The metacognitive survey and comprehension tasks pretests indicated that the lower ability readers performed much more poorly than the better ability readers on these tasks. However, the posttest results showed reduced differences between groups, indicating that a differential learning effect had taken place and the lower ability readers had gained more from the instructional treatment than the higher ability readers. Gender differences existed on the pretest results of the metacognitive awareness survey and the comprehension tasks with the females performing significantly better than the males. On the posttests of these tasks, however, reduced differences were found, indicating that a differential learning effect had taken place with the males gaining more from the instructional treatment than the females. However, the metacognitive self-management pretest survey showed no significant difference between genders; but the posttest of this survey did find a significant gender difference, with the females performing better than the males. This result was believed to have occurred because the two groups were equally disadvantaged at the time of the pretest yet the females were better prepared to benefit from and internalize instruction in terms of metacognitive self-management and so performed better on the posttest.

On the basis of the findings of this study, and within the scope of the limitations of the design, certain implications for classroom practice can be drawn. The metacognition pretest scores indicated that the students in this study lacked understanding of the processes involved in making meaning from expository science text, particularly the students with lower reading ability. The reading comprehension pretests emphasized this lack of understanding of the reading processes in the lower results achieved by the students on the comprehension tasks, again, especially those students with lower reading ability. The positive and significant gains made on the posttests in metacognitive awareness, metacognitive self-management, and reading comprehension indicate that metacognitive strategies and reading strategies can have a powerful influence on Grade 7 students' reading of expository science text and that these strategies are amenable to instruction and transfer.

Explicit instruction of metacognition in terms of getting the students to 'think about their thinking' showed very promising results in this study. The students were taught to take positive steps toward preparing to make meaning from text by accessing their prior knowledge, setting a purpose for reading, and previewing the general pictorial and textual layout of the text. They were taught the rationale behind these steps so that the strategies were meaningful to them. During reading students were taught to monitor their comprehension and recognize when they were not understanding the gist of the text. By paying attention to the main ideas as they read, using context to discern word meaning, and summarizing paragraphs and passages after reading, the students began to understand how these reading strategies help them make meaning of what they are reading.

The 22 weeks of science instruction with embedded explicit strategy instruction demonstrated significant effects on metacognitive awareness, self-management, and reading comprehension. The increased associations between awareness and comprehension and self-management and comprehension support claims drawn from narrative reading research, but the correlations indicate that the majority of the variance in reading comprehension was not accounted for by metacognition.

These results illustrate the impact that explicit instruction can have on science reading ability. The instruction focussed on a few well chosen strategies that were used over the duration of the instruction following a consistent model of instruction. The impact of the instruction may partially be due to the content covered—nature of science and technology and basic science processes applied to matter and living organisms. The desired image of an efficient, effective science reader involves insights into the nature of science and science text, the interactive-constructive nature of science reading, and the strategies used in science reading. It is more likely that the actual content covered in the three units of science made significant contributions to the overall effects.

The sociocultural context of the classroom and the teacher's role within that context are the keys to the success of teaching reading and metacognitive strategies. The teacher must engage the students "in a cooperative process of inquiry and self-improvement in which both teacher and student seek to refine respective skills and knowledge" (Ruddell & Unrau, 1994, p. 1023). It is important that the teacher set an atmosphere that is both positive and motivating. The students must feel that success is within their reach and worth the effort. The students who made the most gains in this study, those with the lowest ability in reading, grew not only in metacognitive awareness, metacognitive self-management, and reading comprehension but also in self-esteem and confidence. They were the disbelievers at the beginning of the study, the students who had never had much success with reading. Yet, they became the most animated contributors to class discussions on all sorts of topics including the strategies of reading as the study progressed.

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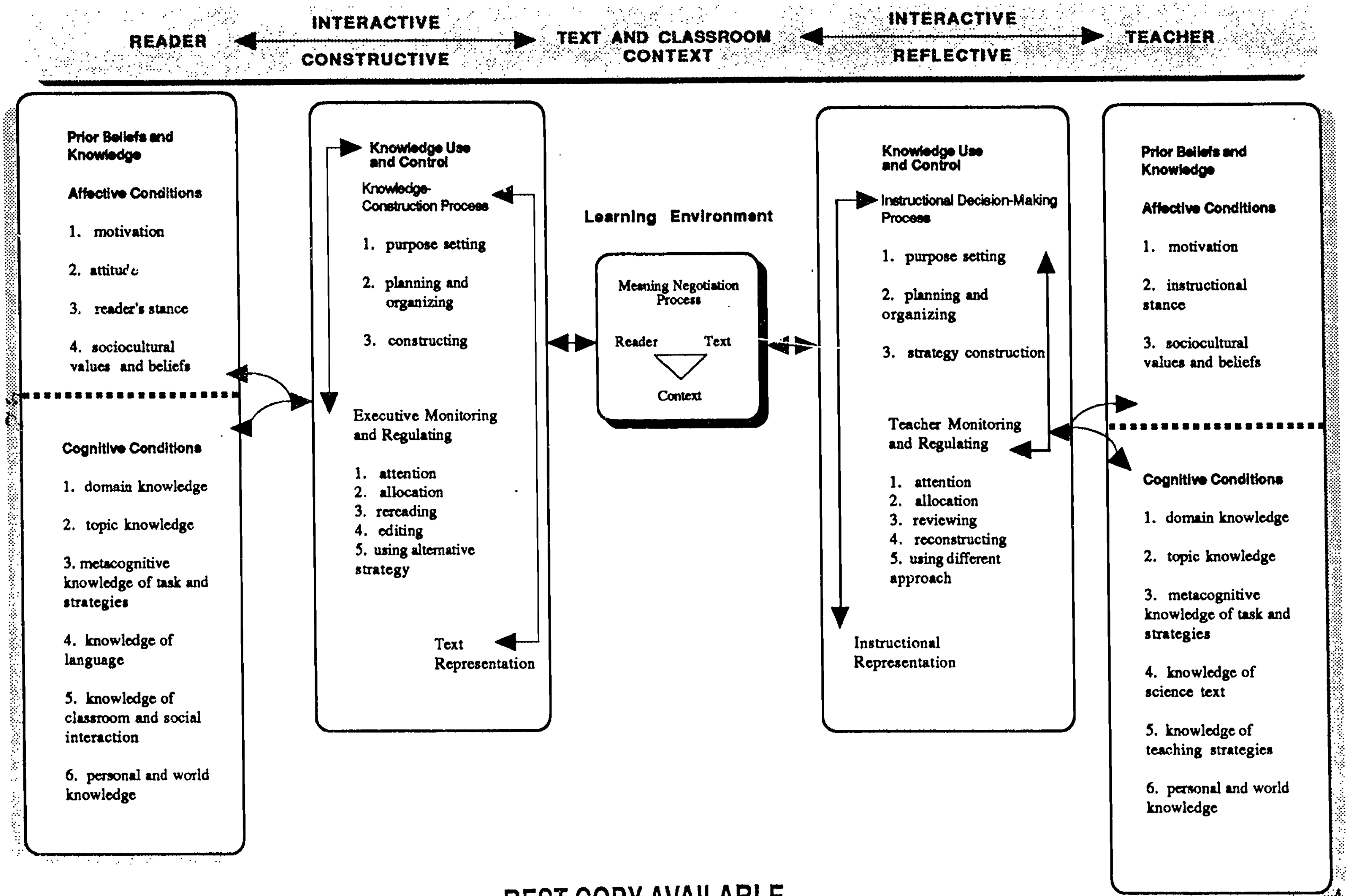
Figure 1
Reading as a Meaning-Construction Process: The Reader, the Text, and the Teacher
(adapted from Ruddell & Unrau, 1994)



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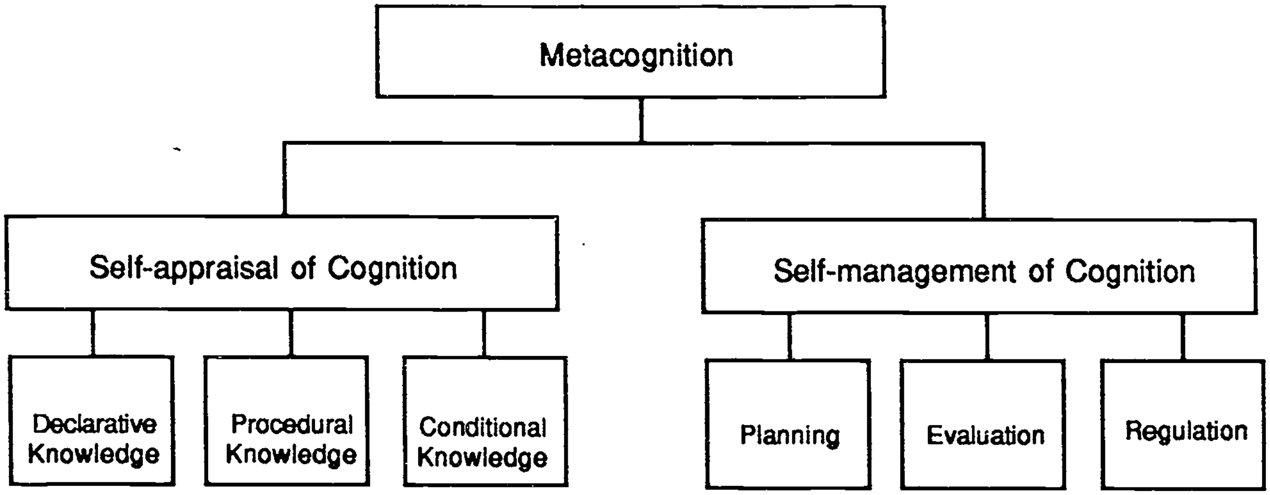

Figure 2: Metacognition (Jacobs & Paris, 1987)

Table 1: Descriptive Statistics for Metacognitive Awareness.

	Pretest			Posttest		
Group	Mean	SD	n	Mean	SD	n
Total Group	84.22	14.58	27	103.96	14.24	27
Reading Ability						
Low	76.64	15.02	11	101.91	16.11	11
Middle	85.09	10.34	11	101.09	13.10	11
High	99.00	10.82	5	114.80	7.69	5
Gender						
Female	91.85	13.67	13	110.08	7.55	13
Male	77.14	11.86	14	98.29	16.76	14

Table 2: Descriptive Statistics for Metacognitive Self-Management.

	Pretest			Posttest		
Group	Mean	SD	n	Mean	SD	n
Total Group	13.96	3.29	27	17.81	3.35	27
Reading Ability						
Low	12.64	2.38	11	17.18	4.47	11
Middle	14.27	3.52	11	18.18	2.44	11
High	16.20	3.70	5	18.40	2.51	5
Gender						
Female	14.46	3.62	13	19.46	2.03	13
Male	13.50	3.01	14	16.29	3.67	14

Table 3: Descriptive Statistics for Reading Comprehension.

	Pretest			Posttest		
Group	Mean	SD	n	Mean	SD	n
Total Group	5.19	1.66	27	6.93	1.63	27
Reading Ability						
Low	4.36	1.12	11	6.24	1.56	11
Middle	5.27	1.90	11	7.06	1.00	11
High	6.80	0.84	5	7.67	0.33	5
Gender						
Female	5.62	1.56	13	6.92	1.09	13
Male	4.79	1.72	14	6.76	1.48	14

Table 4: Correlated t-Test of Pre/Post Changes in Metacognition and Comprehension (N = 27).

Variable	Pretest ($\bar{x}$, SD)		Posttest ($\bar{x}$, SD)		t-Test
Awareness	84.22	(14.58)	103.96	(14.24)	6.75*
Self-Management	13.96	(3.29)	17.81	(3.35)	4.37*
Comprehension	5.18	(1.67)	6.93	(1.64)	5.12*

* Denotes $p \leq .001$ (two-tailed)

Table 5: ANCOVA of Metacognitive Awareness Posttest Results by Reading Ability.

Variable	Degree of Freedom	Mean Squares	F-ratio	p-value
Covariate (Pre-Awareness)	1	1041.54	6.00	0.022
Reading Ability	2	120.26	0.69	0.510
Residual	23	173.52		

Table 6: ANCOVA of Metacognitive Self-Management Posttest Results by Reading Ability.

Variable	Degree of Freedom	Mean Squares	F-ratio	p-value
Covariate (Pre-Self-Management)	1	0.70	0.06	0.817
Reading Ability	2	3.48	0.28	0.757
Residual	23	12.37		

Table 7: ANCOVA of Reading Comprehension Posttest Results by Reading Ability.

Variable	Degree of Freedom	Mean Squares	F-ratio	p-value
Covariate (Pre-Comprehension)	1	5.26	3.57	0.071
Reading Ability	2	1.81	1.23	0.311
Residual	23	1.47		

Table 8: ANCOVA of Metacognitive Awareness Posttest Results by Gender.

Variable	Degree of Freedom	Mean Squares	F-ratio	p-value
Covariate (Pre-Awareness)	1	1041.54	6.31	0.019
Reading Ability	1	267.77	1.62	0.215
Residual	24	165.15		

Table 9: ANCOVA of Metacognitive Self-Management Posttest Results by Gender.

Variable	Degree of Freedom	Mean Squares	F-ratio	p-value
Covariate (Pre-Self-Management)	1	0.68	0.07	0.790
Gender	1	67.47	7.23	0.013
Residual	24	9.33		

Table 10: ANCOVA of Reading Comprehension Posttest Results by Gender.

Variable	Degree of Freedom	Mean Squares	F-ratio	p-value
Covariate (Pre-Comprehension)	1	5.26	3.37	0.079
Gender	1	0.03	0.02	0.894
Residual	24	1.56		