DOCUMENT RESUME

ED 356 134 SE 052 939

AUTHOR Yore, Larry D.; Craig, Madge T.
TITLE Middle School Students' Metacognitive Knowledge about Science Reading and Science Text: Objective Assessment, Validation, and Results.
PUB DATE 92
NOTE 30p.; For the interview study, see SE 052 942.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Measurement; Constructivism (Learning); Factor Analysis; Intermediate Grades; Interviews; Junior High Schools; Knowledge Level; Learning Strategies; *Measures (Individuals); *Metacognition; Middle Schools; Models; Reader Response; *Reading Comprehension; Reading Materials; Science Education; Science Instruction; *Science Materials; Test Construction; Validity
IDENTIFIERS *Middle School Students

ABSTRACT

Much has been written about the value of metacognition. However, little research has identified subsumed intellectual factors, logical operators, and cognitive functions; or has established clear relationships between metacognition and science cognition. This paper presents a study to build a strategic metacognitive model of an efficient, successful science reader based on research results. Other goals are to develop an objective assessment instrument, to validate the instrument, and to provide a profile of middle school students' metacognitive knowledge about science reading and science text. The objective test and interview protocols were developed based on a matrix associated with a theoretical model that crossed 21 comprehension strategies with 3 levels of knowledge: declarative, procedural, and conditional. The objective tests were validated using a group of 532 volunteer students from grades 4 (n=113), 5 (n=108), 6 (n=109), 7 (n=93), and 8 (n=109), and the interview protocols with a random selection of 52 students from those groups. Factor analysis of the students' responses to the objective test generated a metacognitive profile of middle school students' knowledge about science reading and science text. Results of the profiles indicated: (1) surface level declarative, procedural, and conditional knowledge for middle school students on the factors tested; (2) significant differences between high ability readers and low ability readers; (3) a gender difference favoring girls; (4) no increase in metacognitive awareness of science reading and science text in middle school students with additional years of schooling; (5) significant differences between metacognitive domains; and (6) specific strategies that regard reading as an interactive-constructive process. (Contains 14 references.) (MDH)

Middle School Students' Metacognitive Knowledge About Science Reading and Science Text: Objective Assessment, Validation, and Results

Larry D. Yore
University of Victoria

Madge T. Craig
University of North Texas

Introduction

The construction of knowledge from concrete experiences, visual information, verbal interactions, and textual materials has received varied emphasis during the last ten years. The constructivist approach to conceptual change has dominated the presentations at recent science research conferences. Millar (1989) cautioned readers not to assume that the constructivist perspective is the only valid model since much learning has occurred without the aid of a conceptual change approach, that a generalizable constructivist instructional strategy may be impossible in light of the personalized nature of the construction process, and that if a conceptual change strategy is proven effective it should be selectively applied to the most difficult conceptual barriers. Successful information and sensory experiences are integrated into existing knowledge structures. This process is clearly an internally regulated personal process enhanced by external supportive scaffolding, influenced by context, affected by prior knowledge, and related to specific intellectual processes.

Metacognition — the awareness and executive control of cognition — may be a construct that will reveal insights about the that, how, why, and when of cognition. Much has been written about the value of metacognition but little basic research has identified subsumed intellectual factors, logical operators, or cognitive functions, or has established clear associations and relationships between metacognition and science cognition. Metacognition is an umbrella construct that has gained popularity within the science education community while its relationship to cognitive strategies, self-managed explorations, and science learning remains fuzzy.

This study attempted to build a strategic metacognitive model of an efficient, successful science reader based on research results, to develop an objective assessment instrument, to validate the instrument, and to provide a profile of middle school students' metacognitive knowledge about science reading and science text. This paper will report briefly on comprehension research, a pilot study, and an interview study. More complete reports on these components are provided earlier in this Paper Set (Rivard & Yore, 1992; Craig & Yore, 1992) or were reported at earlier NARST meetings (Yore & Denning, 1989; Yore & Craig, 1990). The majority of this paper will be devoted to the development and validation of the objective instrument and the results.

Background

Current conceptions of reading closely approximate the constructivist perspective of science learning. Osborne and Wittrock (1983) identified the commonalities in processing information from laboratory experiments, classroom demonstrations, visuals, verbal presentations, and printed materials. The construction of understandings from primary (first-hand experience), secondary (stored audio and visual information), and tertiary (others' interpretations) information sources is a normal expectation of daily life; and effective models of learning must consider the perception and processing of information from these diverse sources. The roles of prior knowledge, concurrent experience, language, and context are central in the interactive-constructive model of reading (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 while responding to a specific contextual influences (Rivard & Yore, 1992; Yore & Shymansky, 1991). The learner, the text, the task, and the context are critical components in the meaning-making process. Applied research must consider the global nature of these interacting components, the supportive scaffoldings provided by other people, and the internal control of the construction process. As individual components or combinations of components change, the interactive system changes. The changes in cognition must be accommodated by the readers' metacognition -- awareness and control of cognition. These executive functions may be automatic or transparent in unstressed situations but become overt and conscious in cognitively demanding situations (Jacobs & Paris, 1987). The dynamics of reading mean that researchers should expect to find statistical interactions between many factors in reading comprehension. These interactions may mask many significant effects if the research designs used did not fully anticipate their existence -- prior knowledge, cognitive demand of task, and social context.

Summaries of reading comprehension research reveal that prior knowledge (episodic and semantic), strategies, affective disposition, metacognition, and context are important in meaning-making (Rivard & Yore, 1992; Yore & Russow, 1989; Yore & Shymansky, 1985). The reviews indicated that limited consideration of science reading and science text existed and no comprehensive model of a science reader existed. The narrative reading research results and analyses of science learning research, goals of science education, nature of science and the scientific enterprise, and science textual materials were synthesized to provide a comprehensive image of an efficient, successful science reader (Yore & Denning, 1989). The desired image was a multifactor description that listed strategic components comprising an effective, fluent science reader. The synthesis process produced clusters of bottom-up and top-down skills, knowledge about science reading, and conceptions of scientific text collected around specific heuristics. Analysis of these clusters indicated they were unified by purpose, decision-making, problem-solving, and communication skills. The clusters were judged to be strategies; "processes [or sequences of processes] that, when matched to the requirements of tasks, facilitate performance" (Pressley, Goodchild, Fleet, Zajchowski & Evans, 1989, p. 303), "steps or actions [taken] to enhance comprehension" (Lysynchuk, Pressley, d'Ailly, Smith & Cake, 1989, p. 460), or "action plans, methods, or a series of maneuvers that reflect the characteristics and demands of the task" (Rivard & Yore, 1992, p. 8).

Yore and Craig (1990) revised the original image by adding a metacognitive dimension orthogonally to the strategies dimension. Jacobs and Paris' (1987) conception of metacognition was selected to define the second dimension of the model. They described metacognition as being composed of self-appraisal (awareness) and self-management (control). Self-appraisal is defined as declarative knowledge (that), procedural knowledge (how), and conditional knowledge (why and when) about cognition. Self-management is defined as strategic planning, evaluation of progress, and regulation of cognition.

A pilot multi-method, multi-trait study attempted to develop four assessment techniques for the strategic self-appraisal part of the model (Yore & Craig, 1990). The results of the pilot study indicated that structured interviews and multiple-choice questions with open response option were suitable techniques to assess the model and that the model should be revised to include a factor regarding knowledge representation — words as symbolic concept labels. Implementation of the revision resulted in a 21 (strategies) by 3 (self-appraisal knowledge) model of the efficient, successful science reader (Figure 1).

Insert Figure 1 about here

Method

The desired image of the efficient, successful science reader served as the blueprint for developing interview questions for structured interview protocols and multiple-choice items with open response option for an objective test. The 21x3 matrix associated with the model provided a table of specifications for 63 cells with specific strategic self-appraisal (declarative, procedural, or conditional) attributes. The interactive, dynamic nature of science reading suggested that the research design should utilize a small group, naturalistic inquiry embedded into a large group survey of middle school students.

Objective Test

Individual objective test items were developed for each of the 63 cells, using the guidelines provided by Jacobs and Paris (1987). Item analysis of responses from the pilot study was used to revise the original 30 items. Additional items were developed for the other 33 cells to complete the 21x3 matrix. Declarative knowledge items assessed "that" related issues about a specific strategy, procedural knowledge items assessed "how" to do a specific strategy, and conditional knowledge items assessed "why" or "when" a reader would use a specific strategy.

The model and associated items were submitted to six reading experts to assess construct validity. Evaluation responses returned from three experts were used to make revisions in wording and slight modifications in strategies.

The 63 items were randomly assigned position in the examination to minimize cueing. The objective test was administered to middle school students to further evaluate reliability and validity.

Structured Interview Protocols

Individual questions related to each cell of the model were developed (see Craig & Yore, 1992). Questions used in the pilot study were revised to reflect the question analysis results. Additional questions were developed to complete the cells of the 21x3 matrix. Interview questions did not replicate the objective test items but assessed the same strategic self-appraisal knowledge.

The interview questions were assigned in groups of three questions (declarative, procedural, conditional) for each strategy to one of five structured protocols. Protocols #1-#4 contained four sets of three questions, and Protocol #5 contained five sets of three questions. These protocols were administered to a random subsample of middle school students who had completed the objective test. The sequence of questions in each protocol was randomized for each student. The resulting data from both the objective test and interview were used to examine the reliability, the construct validity, and the predictive validity of the objective test and to provide a composite profile of middle school students' metacognitive knowledge about science and science text (for interview results see Craig & Yore, 1992).

Data Collection

Students from an interior British Columbia school district served as the sample for this study (N = 532). Five schools, representing a wide variety of socioeconomic conditions, school organizations, and school sizes, volunteered to participate in this study. Volunteer students from grades 4 (N = 113), 5 (N = 108), 6 (N = 109), 7 (N = 93), and 8 (N = 109) completed the 63-item objective test. The gender distribution was 261 females (49%) and 271 males (51%) spread across three reading ability levels (low = 91, average = 282, high = 159).

Fifty-two students were randomly selected by grade level, gender, and reading ability for individual interviews. Three students from this group did not complete both the objective test and interview, reducing the validation subsample to 49 students.

Data were collected by an experienced teacher-interviewer over ten days, 1 1/2 to 2 days per school. The objective test was administered first, followed by some form of instruction other than science and reading or free recreational time to avoid transfer between test and interview.

The objective test was administered in a large group setting within a normal standardized testing ecology. The teacher-interviewer introduced the test directions and aided individual students with clarification questions during the test. All students completed the objective test within 60 minutes.

The individual interviews were conducted in a private area, following the instruction or recreation time, and were tape recorded. Protocols #1-#5 were randomly assigned to students. The order of question sets within the protocol was randomly sequenced for each interview to minimize internal bias. Interviews took between 10 to 15 minutes.

Data Analyses and Results -- Validation

Data Analyses -- Validation

The interviews were transcribed. Question responses from the interviews and item responses from the objective test were scored as comprehensive strategic knowledge (2), surface/incomplete knowledge (1), or no/incorrect knowledge (0). These data were analyzed for reliability (internal consistency, item-item correlations, item-strategy correlations, item-metacognitive knowledge domain correlations, item-total test correlations), sensitivity (response distributions, range of item scores), construct validity (factor analysis, test-interview correlations), and predictive validity (grade level, reading ability, and gender differences for metacognitive test, domains, and strategies). The factor analysis and predictive validity results will be reported in the profile results section since the total sample was required for these statistical treatments.

Results -- Validation

The descriptive data for the validation subsample are provided in Tables 1 and 2. These data served as the foundation to determine internal consistency, item-item associations, item-metacognitive knowledge domain associations, item-total test associations, and response distribution.

Insert Tables 1 and 2 about here

Reliability. The stability of the objective test was explored by assessing the internal consistency, the item-item correlations within a strategic factor, the correlations between items and knowledge-domain scores, and the correlations between items and total score.

The internal consistency was determined using a Crombach Alpha. The analysis yielded an $\alpha = 0.87$ (with full middle school sample, this value was 0.88), which was judged to be acceptable for the purposes intended.

The inter-item correlations indicated that most items for an individual strategic factor were positively associated. An inspection of the 189 item-item correlations within a specific strategic cluster (declarative-procedural, declarative-conditional, procedural-conditional) indicated that 95.8% of the item-item corrections were positive associations. Only one of the eight negative item-item associations was significant ($p \leq 0.05$). Crombach's internal consistency measures for the three items within a specific strategy ranged from $\alpha = 0.01$ to $\alpha = 0.53$ (with full middle school sample, the range was 0.07 to 0.53). Only strategies #6, #7, #9, and #11 had internal consistencies of less than 0.10 (with the full sample, only #6 was less than 0.10). These data indicate that the items within specific strategies appear to assess similar strategic knowledge consistently.

The 21 items within the declarative, procedural, and conditional domains were not consistently associated with positive correlations. The items within each knowledge domain were positively correlated with the subscore for that domain. Internal consistencies for the three metacognitive knowledge domains indicated reasonable reliability within each domain. The Crombach Alpha for the declarative domain was 0.72, for the procedural domain was 0.57, and for the conditional domain was 0.75 (with the full middle school sample, these values were 0.69, 0.70, and 0.75 respectively). These data indicated that items within the declarative, procedural, or conditional domains appeared to consistently assess similar metacognitive knowledge.

Comparison of individual items correlation with the total test indicated 62 items were positively associated with the total test score. The one negative item-total test association was not statistically significant ($p \leq 0.05$), while 50 of the positive item-total test associations were statistically significant ($p \leq 0.05$).

Inspection of response patterns reveals that no item was too difficult or too easy for middle school students. Only one item (#3D) did not produce a full range of responses (0, 1, 2). Inspection of the percentage distribution of students selecting specific responses scored as 0 and 2 indicated that no item response indicating no/incorrect knowledge (0) received more than 60% of the responses and 20 item responses indicating comprehensive strategic knowledge (2) received more than 60% of the responses.

Based on the internal consistencies and the item associations with strategic factors, metacognitive domains and the total self-appraisal measure, the objective instrument appears to be reasonably reliable. Crombach Alphas for the total test and knowledge domain sub-scales were acceptable. The internal consistencies for the three-item strategy sub-scales were as good as could be expected with so few items in each sub-scale.

Validity. The construct validity of the objective test was explored by correlating individual items with related interview questions, items and questions within a strategy, items and questions within a knowledge domain, and related item-question pairs within the total model. Further explorations were conducted using rotated factor analyses of the objective test data. The principle components revealed by the factor analyses were compared to the design specifications based on the 21x3 model of the efficient, successful science reader.

The item-question correlation analyses revealed that two item-question pairs were significant negative associations ($p \leq 0.05$) and 21 item-question pairs were negatively associated ($p > 0.05$). Five item-question pairs were positively associated ($p > 0.05$) and 32 item-question pairs were significantly associated ($p \leq 0.05$). Three item-question correlations could not be calculated since no variation was observed in the interview responses. The weak associations were not totally unexpected because of the difference in cognitive demands of the items and questions. The multiple-choice items required recognition, and the interview questions required free recall (Valencia, Stallman, Commeyras, Pearson & Hartman, 1991). Furthermore, test items and interview questions did not assess the same exact knowledge within the strategic clusters. The negatively correlated item-question pairs were flagged for later consideration in revising the model and the objective test.

The item-question correlations within specific strategic factors indicated that the combined item-question pairs for 16 strategies were positively associated (range of correlations were 0.01 to 0.39). Strategies #4, #11, #17, #19, and #20 were negatively associated (range of correlations were -0.03 to -0.22). Likewise, the item-question correlations within each of the knowledge domains were positively associated (declarative, r = 0.11; procedural, r = 0.17; conditional, r = 0.06.) These results indicate that the response data for the 21 item-question pairs within a specific metacognitive domain appeared to assess similar types of knowledge. The composite item-question pairs for the total test was positively correlated (r = 0.16). This indicates that on the broad spectrum of metacognitive knowledge, the objective items appeared to measure similar information as the interview questions.

Data Analyses and Results -- Middle School Student Profile

Data Analyses -- Middle School Student Profile

The value of any assessment instrument must be in the information it provides. The students' responses (N = 532) were used to explore the test's construct validity by factor analysis, to generate a metacognition profile of middle school students' knowledge about science reading and science text, and to explore the predictive validity of the instrument. This instrument was designed to reflect a strategy by metacognitive knowledge model. It was predicted that a rotated factor analysis would yield a series of principle components unified by the fundamental assumptions of design -- declarative knowledge, procedural knowledge, conditional knowledge, general strategies related to science reading, general strategies related to science text, and specific strategies.

The rotated factor analyses of the 63 test items across all metacognitive knowledge domains and strategic factors revealed several principle components of item clusters involving knowledge about science reading, science text, and specific strategies (Table 3). The unifying assumptions were difficult to determine. It appears as if principle components 1, 2, 3, and 7 are mainly unified along metacognitive knowledge domains, i.e., conditional, declarative, procedural and procedural respectively. Principle components 4, 5, 6, and 8 appear to be interactive clusters of metacognitive factors related to strategies, science reading, and science text. Principle component 4 appears to involve assessing text and study skills; principle component 5 involves selecting, identifying, and monitoring specific strategies; principle component 6 involves general reading and text knowledge; while principle component 8 involves a collection of general reading, text, and strategy knowledge. The residual component appears to mainly contain procedural knowledge.

Insert Table 3 about here

Based on the factor analysis results for the total sample, it was decided to run a series of factor analyses on data from the high reading group only and the high and average reading groups for all 63 items and a selected sub-set of items. None of these secondary approximations yielded more clearly unified principle components along strictly metacognitive domain or strategic factor dimensions.

These results suggested that a more powerful modeling technique was required to explore the validity of the desired image of an efficient, successful science reader and the objective test. Linear structural modeling (LISREL-7) was judged to provide an appropriate statistical procedure to explore and confirm the links between the model and the test. This analysis will be conducted in the near future.

Based on these inconclusive explorations of validity, the objective test was not revised. The following results must be interpreted with a reasonable degree of caution. The lack of validity appears to be a combination of the fuzzy nature of metacognition, the transitional knowledge about science reading and science text of middle school students, the precision of specific test items, and the model of the ideal science reader.

Results -- Profiles

The descriptive results for the combined Middle School sample are provided in Table 4. These results indicate that middle school students have at least surface/incomplete level ($x \geq 0.77$) declarative, procedural, and conditional knowledge about all factors tested. Performance on five declarative questions (#3D, #8D, #9D, 13D, 19D), four procedural questions (#12P, #14P, #18P, #19P), and nine conditional questions (#7C, #9C, #10C, #12C, #16C, #18C, #19C, #20C, #21C) were judged to be approaching a comprehensive strategic level of knowledge ($x > 1.50$). Knowledge about all strategies was judged to be at least at the surface/incomplete level; and strategies #7, #9, #18, and #19 were judged to be at the comprehensive strategic level. The total metacognitive knowledge and domain knowledge were judged to be at the surface/incomplete level.

Insert Table 4 about here

Researchers have suggested that metacognitive knowledge about science reading and science text improves with grade level and is higher for good readers than poor readers. Grade level is a global developmental factor that combines the influences of additional expositive text exposure, increased prior knowledge, and improved cognitive abilities. Reading ability has been commonly assessed by using standardized test results, task performance, and teachers' global evaluations. This study utilized teachers' global evaluations that were based on intuitive assessments of students' classroom performance on various print-related tasks, informal assessments, and general academic achievement.

The predictive validity of this instrument and a further clarification of the results were explored by statistically testing the observed differences between grade levels, reading ability, and gender. A series of one-way ANOVAs or t-Tests was conducted on the data. The

ANOVAs revealed significant ($p \leq 0.05$) differences between grade levels for specific measures (strategies #2, #5, #7, #8, #13, #15, #19, #21; all domains and total test) and between reading ability levels for all strategies, domains, and total test (except strategies #6 and #17). Scheffe comparisons were conducted on these significant grade level dimensions; the results revealed that grade 8 results were generally significantly ($p \leq 0.05$) lower than grade 7 and grade 6 results. The differences between grades 4, 5, 6, and 7 students were not significant ($p > 0.05$) and were not consistently ordered. Students judged to have high reading ability performed significantly ($p \leq 0.05$) better than average (except strategies #1, #2, #9, #14) and low reading ability students. The average reading ability group performed significantly ($p \leq 0.05$) better than the low reading ability group on most measures (strategies #1, #4, #7, #9, #12, #13, #16, #18, #19, #20, #21; all domains and total test).

A series of two group t-Tests was used to analyze gender differences on specific strategic factors, the metacognitive domains and the total measure. These analyses indicated that female middle school students had significantly ($p \leq 0.05$) greater knowledge about science reading and science text than male middle school students on most measures (except strategies #2, #3, #4, #5, #6, #8, #9, #15, #17).

A series of one-way ANOVAs was conducted on strategic and self-appraisal dimensions for the combined sample, females, males, grade 4 students, grade 5 students, grade 6 students, grade 7 students, grade 8 students, low ability readers, average ability readers, and high ability readers. Analyses of differences between individual strategies and knowledge domains revealed significant ($p \leq 0.05$) difference between strategies and between knowledge domains. Statistical analyses of the data on 21 strategies indicated significant ($p \leq 0.05$) differences existed for the combined sample, females, males, individual grade levels, and reading abilities. The Scheffe procedure revealed that the source of the variance differed for each grouping; but generally performances on strategies #1, #9, #18, and #19 were significantly better than the performances on strategies #2, #4, #6, #15, and #17.

Analyses of the domain scores for the combined sample, by individual grade-level groups, by separate gender, and by separate reading-ability groups indicated significant ($p \leq 0.05$) differences between performance on declarative, procedural, and conditional knowledge items. The Scheffe procedure revealed that the sources of the significance were between declarative and procedural domains and conditional and procedural domains for all groupings. No significant ($p > 0.05$) differences were found between declarative and procedural domains. These results indicate that declarative, procedural, and conditional knowledge of a specific strategy is not hierarchical.

Discussion

Garner (1987) suggested that "metacognition is a relatively new label for a body of theory and research that addresses learners' knowledge and use of their own cognitive resources" (p. 1). She stressed the enormous potential of this fuzzy construct but cautioned that the clarity of the construct varies drastically across the disciplines. Jacobs and Paris (1987) stressed the need to make metacognitive awareness and control conscious and public. This study attempted to clarify the concept of metacognitive awareness of science reading and science text and to make this awareness public by means of test items designed around a model of an efficient, successful science reader. These attempts were varied in their results.

The test's reliability was reasonable but the test's validity remains questionable. Additional analyses and modeling are needed. The results reported are provided with a cautionary note, because it is important that these data are made available to other researchers working with a comprehensive image of science reading that include metacognitive strategic dimensions.

The results clearly indicated that middle school students have limited knowledge about science reading and science text. The results identify several strategic factors (#2, #4, #6, #15, #17) that could be addressed by explicit instruction that provides the declarative, procedural, and conditional knowledge about the strategies.

The significant differences between high ability readers and low ability readers implies that metacognitive knowledge may make a meaningful contribution to global reading ability. It is not known whether increased metacognitive awareness will result in increased self-management, science reading comprehension, and science achievement. Therefore, explicit instruction directed at increasing students' knowledge about science reading and science text may not be a valid approach toward improving science reading comprehension and requires further exploration.

The grade level results were unexpected. It appears that middle school students do not increase their metacognitive awareness of science reading and science text with additional years of schooling as they do for narrative text. This may be explained by the lack of instruction about expositive text or the lack of continued consideration of reading in science at the upper middle school years. The host school district has made an explicit attempt to embed reading and thinking instruction into the elementary school curriculum (K-7) but it is difficult to determine if this explicit effort is continued into the junior high school years.. These efforts did not specifically focus on science reading.

The significant gender difference favoring girls might be a result of effort. Frequently, female students assign higher value, attention, and effort to reading. The increased metacognitive awareness of science reading and science text does not appear to result in significantly higher science achievement for females in middle school grades. This result suggests that factors other than science reading contribute to conceptual science learning.

The significant difference between metacognitive domains is a surprise, since non-significant differences were found in the pilot study and interview study (Yore & Craig, 1990; Craig & Yore, 1992). The interesting aspect was that declarative, procedural, and conditional knowledge results were not hierarchical as predicted from the model. This may be a result of no explicit instruction on science reading and science text. It is likely that students construct their metacognitive knowledge about science reading and science text from unstructured experiences with science texts. The knowledge is developed in a need-to-know basis and by necessity the procedural (how) and conditional (why and when) aspects are developed along with the declarative (that) aspect for any strategy. Procedural knowledge lags behind declarative and conditional knowledge because the procedures are difficult to explain and detect.

The results indicated specific strategies that regard reading as an interactive-constructive process; that science text is not absolute truth, it has unique text structure, words are labels for experiences and ideas, and comprehension strategies must be used to detect fact, opinion, and beliefs; that appropriate strategies must be selected for specific reading tasks; and that self-confidence is a critical factor in science reading would benefit from explicit instruction. Garner (1987) stated

> Though we do not have a theory of the developmental mechanisms that move relatively unknowledgeable, nonmonitoring, strategically naive individuals to a more metacognitively sophisticated state, we do have a rich [narrative] research base documenting that the movement occurs. (p. 31)

She continued that it is unknown whether readers who differed in knowledge about reading actually differed in reading performance. It is these relationships between metacognitive awareness, metacognitive control and science learning, whether explicit comprehension instruction affects these relationships, and if an objective test can detect changes in metacognitive awareness that require further attention. It is apparent that middle school students perceive science text as being the truth and it should over-rule non-print experiences. This appears to indicate that students have a relatively traditional view of science.

References

Craig, M.T. & Yore, L.D. (1992). Middle school students' metacognitive knowledge about science reading and science text: An interview study. A paper presented at the National Association for Research in Science Teaching Annual Meeting, Boston, MA, March 24.

Garner, R. (1987). Metacognition and reading comprehension. Norwood, NJ: Ablex.

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

Lysynchuk, L.M., Pressley, M., d'Ailly, H., Smith, M. & Cake, H. (1989). A methodological analysis of experimental studies of comprehension strategy instruction. Reading Research Quarterly, 24, 458-470.

Millar, R. (1989). Constructive criticisms. International Journal of Science Education, 11, 587-596.

Osborne, R.J. & Wittrock, M.C. (1983). Learning science: A generative process. Science Education, 67, 489-508.

Pressley, M., Goodchild, F., Fleet, J., Zajchowski, R. & Evans, E.D. (1989). The challenges of classroom strategy. Elementary School Journal, 89, 301-342.

Rivard, L. & Yore, L.D. (1992). Review of reading comprehension instruction: 1985-1991. A paper presented at the National Association for Research in Science Teaching Annual Meeting, Boston, MA, March 24.

Valencia, S.W., Stallman, A.C., Commeyras, M., Pearson, P.D. & Hartman, D.K. (1991). Four measures of topical knowledge: A study of construct validity. Reading Research Quarterly, 26, 204-233.

Yore, L.D. & Craig, M.T. (1990). A preliminary report: An assessment of what grade 5 students know about science text and science reading (ERIC Document Reproduction Service No. ED 319 589).

Yore, L.D. & Denning, D. (1989). Implementing change in secondary science reading and textbook usage: A desired image, a current profile and a plan for change (ERIC Document Reproduction Service No. ED 305 270).

Yore, L.D. & Russow, J.E. (1989). Toward a unified conception of thinking (ERIC Document Reproduction Service No. ED 305 270).

Yore, L.D. & Shymansky, J.A. (1985). Reading, understanding, remembering and using information in written science materials. (ERIC Document Reproduction Service No. ED 258 825).

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

The desired image of an efficient, successful reader of science text materials should be a person who is able to:

1. realize that science reading is an interactive/constructive process by which you construct meaning from personal experience, recorded experiences of other people and the context of the reading.

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

3. develop a sense of the motivation and value for the reading and feel confident that the reading will help them to understand, reinforce, and enrich personal experiences, interests, and needs, and to solve problems.

4. select reading strategies appropriate to the needs of the reading process, for example, when the purpose of the reading is to obtain an overview of the text, the student uses skimming, key words, titles and headings, and first sentences in paragraphs to retrieve the main ideas.

5. realize that the text is not an absolute truth and that all science writing is a form of interpretation and, at least to some extent, all science writing may be a distortion or simplification of information and ideas that have been developed or recorded through the processes of science.

6. have self-confidence in their reading abilities and realize that a comprehension problem may result from poorly written text or abstract ideas, and not just a personal comprehension block.

7. enjoy science reading and are likely to read science materials outside the prescribed text, and they pursue personal interests in science topics through science reading materials.

8. assess their own personal skills as learners and choose strategies for reading the text that fit their self-assessment and avoid reading difficult information without access to prior declarative knowledge (critical vocabulary and key background concepts) or prior procedural knowledge (plans to review and re-process difficult ideas or concepts).

9. use visual adjuncts in texts, such as graphs, charts, and photographic reproductions to help clarify, organize, reinforce, enrich, or verify the meanings they derive from the text.

Figure 1. The Desired Image of an Efficient, Successful Reader of Science Text Material

10. use efficient vocabulary development skills to determine the meaning of words from cont t; to dissect words into prefixes, suffixes and root-words; to utilize classification, concept maps, metaphors, and analogues to show relationships of key words; and to use mnemonic aids to help remember key words.

11. identify main ideas in a text, delineate supporting ideas, and rephrase ideas to show logical connections and hierarchical relationships explicit or implicit in the text.

12. summarize text passages using the following macrorules: delete redundancies, delete trivia, provide superordinates, or select topic sentences, or invent topic sentences when missing.

13. evaluate text passages for plausibility, completeness, and interconnectedness by using their available knowledge to correct mistakes in science text writing or to fill in missing information necessary to make the text plausible.

14. ask themselves questions about the readings that require comprehension and reflect the purpose(s) for reading the textual material.

15. use inferential and applied comprehension skills to critically synthesize, analyze, evaluate, and apply information regarding fact and opinion, bias, generalizations, causal relationships, and distinctions.

16. utilize efficient search-ahead procedures that allow them to construct meaning from related or linked information in other parts of the sentence or paragraph.

17. identify a variety of text structures including description, simple listing, chronological ordering, compare-contrast, cause-effect, and problem-solution and select reading strategies appropriate to the text structures they encounter.

18. monitor their own successes at understanding the reading information as the reading progresses and detecting discrepancies in light of the established purpose, and consciously adopt or determine strategies to review the text information, which help create a better fit between their schema and the perceived meaning of the text, carry out these strategies, and re-assess the goodness-of-fit for the reviewed textual information and their understandings.

19. adjust their comprehension monitoring to more conscious levels when demands of the reading increase, when difficulties are perceived, and when comprehension is blocked.

20. choose appropriate study skills when there is a need to remember detailed information from text, such as summarizing, outlining, peer testing, and reciprocal teaching.

21. create organized mental images of information in order to help fit the information into existing schema and to help encode the information into long term memory.

Figure 1 (Contd.)

Table 1

Mean and Standard Deviation for Declarative, Procedural and Conditional Items, Strategies and Metacognitive Domains (N = 49).

Strategy #	Declarative	Procedural	Conditional	Strategy
1	1.27, 0.73	1.51, 0.77	1.47, 0.74	1.42, 0.51
2	1.37, 0.79	0.84, 0.62	1.12, 0.78	1.11, 0.50
3	1.84, 0.37	0.92, 0.81	1.35,0.83	1.37, 0.46
4	1.10, 0.51	0.90, 0.47	1.37, 0.73	1.12, 0.36
5	1.27, 0.84	1.29, 0.82	1.25, 0.69	1.27, 0.50
6	1.37, 0.67	1.18, 0.64	1.08, 0.93	1.21, 0.45
7	1.37, 0.60	1.57, 0.58	1.71, 0.58	1.55, 0.34
8	1.59, 0.64	1.45, 0.54	1.45, 0.71	1.50, 0.45
9	1.63, 0.60	1.41, 0.71	1.61, 0.70	1.55, 01.39
10	1.57, 0.65	1.35, 0.75	1.45, 0.82	1.46, 0.51
11	1.67, 0.66	1.16, 0.97	1.45, 0.74	1.43, 0.47
12	1.61, 0.57	1.63, 0.73	1.43, 0.79	1.56, 0.44
13	1.61, 0.67	1.41, 0.79	1.29, 0.68	1.44, 0.50
14	1.27, 0.61	1.69, 0.65	1.45, 0.82	1.47, 0.50
15	1.12, 0.78	0.80, 0.87	1.25, 0.86	1.05, 0.58
16	1.39, 0.79	1.08, 0.61	1.45, 0.71	1.31, 0.44
17	1.29, 0.84	1.33, 0.77	0.98, 0.92	1.20, 0.53
18	1.00, 0.89	1.55, 0.71	1.69, 0.62	1.42, 0.54
19	1.61, 0.53	1.57, 0.61	1.76, 0.52	1.65, 0.37
20	1.22, 0.87	1.18, 0.64	1.71, 0.50	1.37, 0.42
21	1.35, 0.75	1.25, 0.72	1.76, 0.52	1.45, 0.42
Domain	1.41, 0.27	1.29, 0.23	1:41, 0.30	

Table 2

Mean, Standard Deviations, and (Number of Students Interviewed) for Declarative, Procedural and Conditional Questions, Strategies and Metacognitive Domains.

Strategy #	Declarative	Procedural	Conditional	Strategy
1	1.00, 0.00 (10)	1.30, 0.48 (10)	1.00, 0.47 (10)	1.10, 0.23 (10)
2	0.80, 0.42 (10)	0.60, 0.52 (10)	0.80, 0.92 (10)	0.73, 0.38 (10)
3	1.00, 0.54 (8)	0.75, 0.71 (8)	1.13, 0.35 (8)	0.96, 0.38 (8)
4	0.82, 0.60 (11)	0.91, 0.30 (11)	0.91, 0.30 (11)	0.88, 0.23 (11)
5	1.50, 0.76 (8)	1.38, 0.74 (8)	1.25, 0.71 (8)	1.38, 0.38 (8)
6	1.00, 0.47 (10)	1.50, 0.53 (10)	0.20, 0.42 (10)	0.90, 0.32 (10)
7	1.40, 0.52 (10)	1.40, 0.70 (10)	1.90, 0.32 (10)	1.57, 0.32 (10)
8	1.60, 0.70 (10)	1.10, 0.32 (10)	1.50, 0.85 (10)	1.40, 0.38 (10)
9	1.60, 0.70 (10)	1.00, 0.67 (10)	0.90, 0.32 (10)	1.17, 0.39 (10)
10	1.55, 0.52 (11)	1.18, 0.41 (11)	0.91, 0.54 (11)	1.21, 0.23 (11)
11	1.00, 0.00 (8)	1.63, 0.52 (8)	1.38, 0.52 (8)	1.33, 0.25 (8)
12	1.00, 0.67 (10)	0.90, 0.57 (10)	0.90, 0.57 (10)	0.93, 0.38 (10)
13	0.91, 0.54 (11)	1.27, 0.79 (11)	1.18, 0.60 (11)	1.12, 0.37 (11)
14	0.80, 0.42 (10)	0.90, 0.32 (10)	1.10, 0.57 (10)	0.93, 0.26 (10)
15	0.30, 0.68 (10)	0.50, 0.71 (10)	1.00, 0.67 (10)	0.60, 0.52 (10)
16	1.36, 0.51 (11)	1.27, 0.65 (11)	0.91, 0.70 (11)	1.18, 0.41 (11)
17	0.70, 0.68 (10)	0.60, 0.84 (10)	1.20, 0.63 (10)	0.83, 0.39 (10)
18	1.00, 0.54 (8)	1.00, 0.76 (8)	1.38, 0.74 (8)	1.13, 0.35 (8)
19	0.80, 0.63 (10)	1.20, 0.63 (10)	0.80, 0.63 (10)	0.93, 0.44 (10)
20	0.90, 0.88 (10)	0.90, 0.32 (10)	0.50, 0.53 (10)	0.77, 0.35 (10)
21	0.60, 0.52 (10)	0.80, 0.63 (10)	1.20, 0.42 (10)	0.87, 0.23 (10)
Domain	1.05, 0.36 (49)	1.05, 0.38 (49)	1.01, 0.31 (49)	

Table 3

Test Items and Loading Weights for the Principle Components of the Varimax Rotation Factor Analysis of Middle School Students (N = 532).

Principle Component, Item Number (Strategic Factor, Metacognitive Domain and Loading Weight)

1	2	3	4	5	6	7	8	Residual
16c (0.56)	18c(0.62)	12p(0.61)	20c(0.68)	4c(0.65)	9p(0.69)	8p(0.56)	9d(0.69)	2p
7p(0.56)	3d(0.54)	21p(0.61)	13d(0.60)	18d(0.41)	3c(0.93)	16p(0.51)	11c(0.42)	2c
11d(0.55)	21c(0.52)	20p(0.52)	13c(0.39)	17c(0.31)	2d(0.35)	1p(0.46)	8d(0.21)	4d
12c(0.54)	17d(0.51)	11p(0.37)	1d(0.38)	18p(0.30)	1c(0.33)	10d(0.38)		4p
9c(0.52)	14p(0.41)	7c(0.29)	19c(0.21)			17p(0.31)		5p
19p(0.51)	19d(0.34)	15c(0.20)						6p
8c(0.49)	2d(0.25)							6c
13p(0.49)	21d(0.23)							10p
12d(0.47)	16d(0.20)							14p
6p(0.39)								14c
10c(0.37)								15p
7c(0.32)								20d
5d(0.26)								
5c(0.23)								
15c(0.23)								

Table 4

Item, Strategy and Domain Means and Standard Deviations (N=532)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.
1	1.20, 0.75	1.37, 0.79	1.45, 0.70	4.01, 1.50
2	1.42, 0.72	0.83, 0.56	1.14, 0.78	3.39, 1.29
3	1.76, 0.51	1.10, 0.85	1.49, 0.71	4.35, 1.35
4	1.16, 0.58	0.98, 0.53	1.29, 0.78	3.43, 1.15
5	1.28, 0.79	1.41, 0.79	1.23, 0.75	3.93, 1.52
6	1.22, 0.70	1.16, 0.60	0.96, 0.94	3.34, 1.35
7	1.52, 0.62	1.42, 0.69	1.69, 0.59	4.63, 1.28
8	1.57, 0.65	1.34, 0.66	1.43, 0.71	4.34, 1.30
9	1.63, 0.63	1.43, 0.71	1.58, 0.68	4.63, 1.24
10	1.48, 0.68	1.43, 0.62	1.57, 0.72	4.49, 1.29
11	1.07, 0.97	1.49, 0.80	1.47, 0.71	4.17, 1.64
12	1.46, 0.82	1.53, 0.71	1.55, 0.68	4.46, 1.47
13	1.55, 0.68	1.45, 0.78	1.45, 0.70	4.44, 1.55
14	1.22, 0.63	1.57, 0.72	1.26, 0.85	4.05, 1.48
15	1.20, 0.76	0.79, 0.86	1.35, 0.79	3.34, 1.57
16	1.48, 0.79	1.12, 0.65	1.52, 0.70	4.12, 1.40
17	1.50, 0.76	1.26, 0.77	1.02, 0.91	3.78, 1.53
18	1.17, 0.86	1.60, 0.65	1.79, 0.54	4.56, 1.40
19	1.58, 0.64	1.52, 0.65	1.69, 0.62	4.79, 1.33
20	1.46, 0.80	1.15, 0.66	1.66, 0.63	4.26, 1.31
21	1.40, 0.80	1.22, 0.75	1.64, 0.61	4.26, 1.44
Domain Means, S.D.	29.86, 5.54	26.84, 5.78	29.98, 6.30	86.68, 16.03