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ABSTRACT

This study attempted to verify a strategic metacognition model of an efficient, successful science reader based on an analytical induction of reading research results; develop a valid objective assessment instrument; and provide a profile of middle school students' metacognitive knowledge about science reading, science test, and text reading strategies. A 63-item test was developed and given to 532 students in British Columbia (Canada). Interviews also provided data. Results indicate that middle school students have limited knowledge about science reading, science text, and text reading strategies. High ability readers had significantly different scores on the metacognitive test than did low ability readers. It appears that grade level does not increase metacognitive awareness of science reading and science text. (PR)

Middle School Students' Metacognitive Awareness of Science Reading, Science Text and Science Reading Strategies: Model Verification

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Introduction

The epistemologies people use to construct knowledge from concrete experiences, visual information, verbal interactions, and textual materials have received increased emphasis during the last few years (Linn, Songer & Lewis, 1991). Successful cognition appears to involve an interactive process in which new information and sensory experiences are integrated into existing knowledge structures or existing knowledge structures are reorganized to accommodate the new information and experiences (Carey, 1986). This process is clearly an internally regulated, personal process enhanced by external supportive scaffolding, influenced by context, affected by prior knowledge, and related to higher order thinking (Resnick, 1987).

Metacognition — thinking about your thinking as you are thinking to improve your thinking — appears to be a construct that will reveal insights about the what, how, why, and when of cognition. Much has been written about the fuzziness of metacognition but little basic research has identified subsumed intellectual factors, logical operators and cognitive functions or has established clear associations and relationships between metacognition and science cognition.

This study attempted to verify a strategic metacognitive model of an efficient, successful science reader based on an analytical induction of reading research results, to develop a valid objective assessment instrument, and to provide a profile of middle

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school students' metacognitive knowledge about science reading, science text and science reading strategies.

Background

Current conceptions of reading closely approximate the constructivist perspective of science learning. Osborne and Wittrock (1983) identified the commonalties 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 learni must consider the perception and processing 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 specific contextual influences (Rivard & Yore, 1992). Cognition 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 (Jacobs & Paris, 1987). Craig and Yore (in progress) believed that neither teachers nor students are aware of the number of decisions and the complexity of regulating science reading during comprehension failure. The reader must decide how to resolve comprehension problems, where to seek additional information, what new strategy to select, and who to consult. Complexity appears to be influenced by the readers' interpretation of science, the topic's conceptual abstractness, and the nature of science text.

Summaries of reading comprehension research reveal that prior knowledge (episodic and semantic), strategies, affective disposition, metacognition, and context are important in meaning-making; Yore & Russow, 1989; Yore & Shymansky, 1985). These reviews indicated that limited consideration of science reading, science text and science reading strategies existed, and no comprehensive model of a science reader existed. The 'rrative reading research results and analyses of science learning research, goals of science education, nature of the scientific enterprise, and science textual materials were synthesized to provide a comprehensive image of an efficient, successful science reader (Yore & Craig, 1990; Yore & Denning, 1989). This model contained clusters of bottom-up and top-down skills, knowledge about science reading, and conceptions of scientific text collected around specific heuristics (Figure 1). The skill 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 actic [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. 9).

Insert Figure 1 about here

Garner (1992) suggested that knowledge about and application of reading strategies improve with age (level of schooling) and are more apparent in good readers than poor readers. Frequently females exhibit better reading abilities than do males (Chall, 1983). Pressley, et al (1989) believed that students can develop and utilize far more reading strategies if they receive explicit instruction than they have been able to develop informally. Pearson, Roehler, Dole and Duffy (1992) described an explicit instructional approach that provides motivation, shares information, and nurtures student understanding. Pearson and Dole (1987) suggested research results support explicit modeling, guided practice, consolidation, transfer of ownership and application during strategy instruction. Simonsen and Singer (1992) believed that knowing what students know about reading and reading strategies is the starting point for planning effective content 'ing instruction. Explicit science reading instruction sh ld be embedded in normal science lessons and utilize the actual textual materials students are normally using to provide a realistic context and maximize transfer. Haller, Child and Walberg

(1988) identified middle school years, particularly grades seven and eight, as a promising period for explicit comprehension instruction.

The image of the efficient, successful science reader is a descriptive model based on an analytical induction of reading research results which was heavily focused on narrative text reading. Rivard and Yore (1992) questioned the generalized use of inferences about strategic science reading based heavily on narrative text evidence. Therefore, it is necessary to verify the image of the efficient, successful science reader and establish acceptable validity of any assessment instruments based on the image. Messick (1989) suggested that validity is a process of inquiry. It is helpful to organize the facets of validity into substantive, external and structural components. Substantive validity can be explored by objective expert analysis of the construct and assessment instrument and by comparison of results to a commonly accepted reference. External validity can be examined by testing predictions based on the underlying theory of the construct. Examination of the structural aspects of validity in the present context begins by assuming that reliable, valid science reading data collected from the perspectives of the model will exhibit the structural assumptions utilized to develop the model. Factor analysis techniques and structural equation modeling techniques can be used to examine the adequate fit of data to the fundamental structure of the model.

The goodness-of-fit between model and data can be explored by pre-determining the number and unifying structures of the principal components revealed by the factor analysis (Loehler, 1987). The decision to use orthogonal or oblique factor analysis techniques should be justified by the two-dimensional structure of the model. Principal components of data that closely approximate the structural assumptions of the model are taken as supportive evidence of the model.

Structural equation modeling can be used to test the fit of data to the structures predicted from theory (Hayduk, 1987). The observed responses are considered to be manifestations of a smaller number of underlying factors. The structure of these underlying factors produces the realtionships observed in the manifestations. Computer programs such as LISREL- 7 are used to test the goodness-of-fit of the observed relationships to the postulated structure of the underlying factors. LISREL-7 explores imposed data structures supported by a model as a test of goodness-of-fit. If the observed data structures do not significantly differ from the predicted structures, the model is assumed to be supported.

Method

The desired image of the efficient, successful science reader and Jacobs and Paris' (1987) concept of metacognition served as the blueprint for developing multiple-choice items with open response option for an objective test. Jacobs and Paris defined metacognition as involving two broad categories, each with three sub-categories (Figure 2). Jacobs and Paris stated:

> The appraisal of thinking can be one's abilities or knowledge, or it might involve an evaluation of the task or consideration of strategies to be used. ... Declarative knowledge refers to what is known in a propositional manner. ... Procedural knowledge refers to an awareness of cognitive processes of thinking. ... Conditional knowledge refers to an awareness of the conditions that influence learning. ... Selfmanagement refers to the dynamic aspects of translating knowledge into action. Three types of executive processes can encompass the activities of self-regulated thinking. ... Planning refers to the selective coordination of cognitive means to a cognitive goal. ... Readers can evaluate their understanding as they pause, paraphrase, answer questions, or summarize information. Evaluation of thinking is an ongoing [monitoring] process in any domain. ... Regulation requires an individual to monitor progress and then revise or modify plans and strategies depending on how well they are working. Self-regulation allows the reader to adjust to changing task demands as well as to successes and failures. (pp. 258-259).

The 21x3 matrix associated with the two-dimensional model provided specifications for 63 cells with specific strategic awareness (declarative, procedural, or conditional) attributes.

Insert Figure 2 about here

Objective Test

Individual objective test items were developed for each of the 63 cells. Declarative knowledge items assessed "what" 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 (Figure 3). The 63 items were randomly assigned position in the examination to minimize cueing.

Insert Figure 3 about here

The reliability and validity of the objective test were explored by examining the responses of a random stratified sample (grade level, gender and reading ability) of 49 students (Yore & Craig, in progress). The stratified sample was composed of 10 students from grades 4, 5, 7 and 8 and nine students from grade 6; 25 males and 24 females; and eight low ability readers, 22 average ability readers, and 18 high ability readers. The students completed the objective test and were interviewed using one of five different structured protocols that contained questions that paralleled but were not identical to the objective test item (Figure 3). Four protocols contained four clusters of three questions (declarative, procedural, conditional) associated with a specific strategy. The fifth protocol contained five clusters of three questions. The strategic clusters were randomized within each protocol. Random sequences that appeared to provide cueing were adjusted.

The interview protocols were randomly assigned to groups of students (N_1=10, N_2=10, N_3=8, N_4=11, N_5=10). The interviews were conducted by an experienced interviewer/teacher in a private quiet area and took 10 to 15 minutes. The resulting test and interview responses were scored as comprehensive strategic knowledge (2), surface/incomplete knowledge (1), or no/incorrect knowledge (0). Scoring was completed by two investigators and agreement was reached on all responses.

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 Cronbach Alpha. The analysis yielded an $\alpha = 0.88$, 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 specific strategic clusters (declarative-procedural, declarative-conditional, procedural-conditional) indicated that 95.8% of the item-item correlations were positive associations. Only one of the eight negative item-item associations was significant ($p \leq 0.05$). Cronbach's internal consistency measures for the three items within a specific strategy ranged from $\alpha = 0.07$ to $\alpha = 0.53$. Only strategy #6 had internal consistencies of less than 0.10. These data indicate that the items within specific strategies appear to consistently assess strategic knowledge.

The 21 items within the declarative, procedural, and conditional domains were not totally associated with positive correlations. Internal consistencies for the declarative domain was $\alpha= 0.69$, for the procedural domain was $\alpha= 0.70$, and for the conditional domain was $\alpha= 0.75$. 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 ($p \geq 0.05$), 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. Item difficulty ranged between 0.06 and 0.84, with an average of 0.54.

Based on the internal consistencies, the item associations, the response distributions and the item difficulties, the objective instrument appeared to be reasonably reliable. Internal consistencies for the total test and knowledge domain sub-scales were acceptable. The internal consistencies for the three-item strategy sub-scales were reasonable for three-item sub-scales.

Validity. The substantive validity of the objective test was judged by three content reading experts prior to the study. Their responses were generally supportive, and their corrective suggestions were used to modify items and language of the objective test.

The substantive validity of the objective test was explored further by correlating individual items with related interview questions; specifically, related item-question pairs within the total model, item-question pairs within a strategy, and item-question pairs within a knowledge domain. The item-question correlation analyses for the total test revealed that 37 item-question pairs were positive associations, 23 item-question pairs were negatively associated, and 3 item-question correlations could not be calculated since no variation was observed in the interview responses. These 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 metacognitive knowledge within the strategic clusters.

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), while 5 strategies 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 and the 3 item-question pairs within most strategies 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, thus supporting claims of substantive validity.

The external validity of the objective test was explored by conducting separate one-way analyses of variance (ANOVA) for school level (grades 4, 5, 6, 7, 8), reading ability (high, medium, low) and gender (male, female). The reading ability and gender ANOVAs indicated significant ($p \leq 0.05$) main effects as predicted, favoring higher reading ability and females. The school level ANOVA yielded a non-significant ($p > 0.05$) main effect that may be an artifact of the sample.

The substantive and external validity results support the judgment that the objective test is reasonably valid and appropriate for use in research situations. These results combined with the reliability evidence suggested that the data accessed by the objective test were suitable for use in verifying the image of an efficient, successful science reader.

Sample

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 (below average = 91, average = 282, above average = 159). Reading ability was based on the global assessment of the teachers that considered general text-related performance, reading assignments, and reading test results.

Data Analyses and Results

The objective test results were scored as comprehensive strategic knowledge (2), surface/incomplete knowledge (1), or no/incorrect knowledge (0). These data were analyzed by a series of exploratory and confirmatory factor analyses in which constraints based on various interpretations of the strategic model of a science reader were prescribed. The imposed limitations involved 3, 4, 9, 12 and 21 factors based on the fundamental structures of the model.

The desired image of an efficient, successful science reader described strategic factors related to science reading (interactive-constructive process, self-efficacy, self-confidence, personal satisfaction), science text (text features, text structure, purpose, scientific language, nature of science), and science reading strategies (general strategies: access, select, monitor and regulate; specific strategies: visual adjuncts, vocabulary, main idea, summarizing, inferring, search, visualization). These strategic factors were expanded along the metacognitive awareness dimension to specify declarative knowledge, procedural knowledge and conditional knowledge.

The structural assumptions guided the verification process to explore 3 factor models (science reading, science text, science reading strategies or declarative knowledge, procedural knowledge, conditional knowledge), a 4 factor model (science reading, science text, general science reading strategies, specific science reading strategies), a 9 factor model (crosses of science reading, science text, science reading strategies and metacognitive awareness), a 12 factor model (crosses of science reading, science text, general science reading strategies, specific science reading strategies and metacognitive awareness) and a 21 factor model (strategic factors). Both orthogonal and oblique factor analyses were used to examine the nature of strategic factors and the metacognitive awareness dimensions.

Initial factor analyses indicated that the model of 21 strategic factors was too complex and so simpler interpretations (3, 3x3, 4x3) were addressed (Hayduck, 1987). The principal components for these rotated factor analyses were inspected in an attempt to determine which unifying assumptions were present.

The goodness-of-fit of each interpretation explored the loadings based on maximum weightings and on forced weightings (wt = ≥ 0.20). The forced loading attempted to produce factors that were unified by the specified interpretation (reading-text-strategies, declarative-procedural-conditional, reading-text-general strategies-specific strategies, or a cross of these simpler interpretations). The principal factors based on maximum and forced loadings were compared to the random distribution of items for the specific interpretations.

Based on the orthogonal and oblique factor analysis results, it was decided that the competing structural relationships within the data were masking the structural interpretation of the model and that a more sophisticated analysis was necessary. In an attempt to more clearly reveal the structural relationships, a series of LISREL-7 analyses were performed. Internal correlations and factor analyses results encouraged a preliminary exploratory step-wise LISREL-7 based on potential interpretations of the model with 1 to 12 factors. These results directed the investigators toward a closer examination of a nine factor (3x3) interpretation.

The LISREL-7 analysis constrained each item into one of nine factors: declarative science reading (DSR), declarative science text (DST), declarative reading strategies (DRS), procedural science reading (PSR), procedural science text (PST), procedural reading strategies (PRS), conditional science reading (CSR), conditional science text (CST), and conditional reading strategies (CRS). The Chi-square equaled 2776 (df = 1854, p = 0.00), which indicated that the data did not fit this structural interpretation. Nevertheless, the small residual values were promising.

Up to this point all analyses had been performed on inter-item correlations. Given the low reliability in the correlations, but the promise of the previous analysis, it was decided to cluster the items into testlets corresponding to the 9 factor model. The (testlets) were taken as the basic data for the remaining analyses using a 3-factor interpretation and 4-factor interpretation. The Chi-square (df = 12) was 13.70 (p = 0.32) for the 3-factor interpretation. The Chi-square (df = 15) was 26.59 (p = 0.03) for the 4-factor model.

Examination of residuals from the LISREL-7 results suggest that the 4-factor interpretation was the best fit. The 3-factor interpretation of science reading, science text, and science reading strategies had a non-significant Chi-square and was more parsimonious but the structural coefficients were not distinctively associated with specific factors and the structure did not fit the model. The declarative, procedural, conditional 3 factor was rejected earlier on the significant Chi-square found. Figure 4 illustrates the relationships and structure of the model of a desired image of an efficient, successful science reader. The primary factor demonstrates the unified nature of metacognitive awareness about science reading, science text, and science reading strategies. The three secondary factors illustrate the fundamental structure of the test design. All structural coefficients (except DRS-Reading Strategy) are positive between testlest and appropriate factors and zero between testlets and inappropriate factors. Internal consistencies for the items in the general awareness factor was 0.88, in the science reading factors was 0.69, in science text factors was 0.51, and in the science reading strategies factor was 0.82. The lack of evidence supporting the metacognitive awareness dimension may have resulted from the limited metacognitive knowledge of these middle school students or the fuzziness and inter-dependence amongst declarative, procedural and conditional knowledge about science reading, science text, and science reading strategies. This structure may appear in data from students who have received explicit instruction about science reading, science text, and science reading strategies.

Insert Figure 4 about here

Metacognitive Awareness Profiles

The objective test validated in this study was used to collect data on middle school students. These data and associated descriptive statistics provide base-line references of grades 4, 5, 6, 7 and 8 male and female students classified as above-average, average and below-average readers by their teachers. Tables 1-11 summarize the descriptive statistics for the total group and specific sub-groups.

Insert Tables 1-11 about here

Item responses were scored as no/incorrect knowledge (0), surface knowledge (1), and comprehensive strategic knowledge (2). Mean item values that approximate 2.00 (≥ 1.50) reflect responses that included interactive aspects (text, prior knowledge, experience, other people) and constructive aspects (meaning making not meaning taking); were thoughtful, deliberate, and purposeful; and reflected contemporary views of science, science text, and science reading. Mean item values between 0.51 and 1.49 reflect responses that were generally text driven and included a bottom-up perspective, were skills centered not strategic, emphasized the reader in isolation and utilized a positivistic, empiricistic or rationalistic definition of science and science text. Mean item values that approximate zero (≤ 0.50) reflect responses that were impoverished; were built on inaccurate or incorrect interpretations of science reading, science text, and science; and were internally inconsistent.

Mean strategy values greater than or equal to 4.50, between 1.51 and 4.49, and less than or equal to 1.50 respectively can be ascribed similar qualities as the item values. Mean science reading values ($\geq$ 27.00, between 9.01 and 26.99, $\leq$ 9.00); science text values ($\geq$ 18.00, between 6.01 and 17.99, $\leq$ 6.00); mean science reading strategies values ($\geq$ 31.50, between 16.51 and 49.49, $\leq$ 16.50); and general awareness values ($\geq$ 94.50, between 31.51 and 94.49, $\leq$ 31.50) respectively can be ascribed the same qualitative characteristics as the three classes of item responses.

Inspection of Table 1 utilizing the quantitative references outline indicates that 20 mean item responses and 4 mean strategy responses could be described as comprehensive and strategic, with all other mean values being considered in surface category. Tables 2-11 can be inspected using the ranges of mean values established and similar trends can be found.

Analyses of these data to explore patterns found with narrative reading and narrative text (Chall, 1983; Garner, 1992) were achieved by using a series of analysis of variance (ANOVA) and Sheffe pair-wise comparison of significant main effects. Significant ($p \leq 0.05$) grade level effects were found for science reading, science text, science reading strategies, general awareness, all metacognitive domains, and selected strategies (#4, #6, #7, #8, #9, #12, #18, #21). 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.

The series of ANOVAs and Scheffe comparisons used to analyze gender differences on specific factors, strategies, metacognitive domains, and general awareness indicated that female middle school students had significantly ($p \leq 0.05$) greater knowledge about science reading, science text, science reading strategies, most specific strategies (except #2, #3, #7, #8, #10, #11, #12, #13, #18), metacognitive domains, and general awareness than male middle school students.

The ANOVAs conducted on test data for above-average readers, average readers, and below-average readers indicated significant differences favoring higher ability readers on science reading, science text, science reading strategies, general awareness, most strategies (except #1, #7, #13, #17), and all metacognitive domains. Significant differences were found between average and below-average readers or strategies #1, #4, #5, #6, #9, #11, #13, #16, #19, #20 and #21, all metacognitive domains, the science reading factor, science reading strategies factor, and general awareness factor.

Analyses of the metacognitive domain scores for the combined sample, by individual grade-level groups, by seperate genders, and by seperate 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 conditional 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, science text, and science reading strategies 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 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, science text and science reading stragegies. The results identify several factors that could benefit from 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, science text, and science reading strategies 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 consistently 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 expository text or the lack of continued consideration of reading in science by content specialty teachers 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 was continued into the junior high school years. Furthermore, this school district's 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, science text, and science reading strategies does not appear to be paralleled by significantly higher science achievement for females in middle school grades. This result suggests that factors other than science reading influence 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 Jacobs and Paris

(1987) model. This may result from the lack of explicit instruction on science reading, science text, and science reading strategies. It is likely that when students construct their metacognitive knowledge about science reading, science text, and science reading strategies from unstructured experiences with science texts the knowledge is developed in a need-to-know basis. This interpretation would match Pressley et al (1989) suggestion that explicit instruction will increase awareness and use of reading stratiegies. A second explanation may be the difficulty in testing procedures. Procedural knowledge lags behind declarative and conditional knowledge because the procedures are difficult to explain and detect. Furthermore, the LISREL-7 results that did not indentify declarative, procedural, and conditional knowledge structure suggest that the Jacobs and Paris (1987) model may be imposing a unreasonable degree of precision on metacognitive awareness that was not anticipated by other researchers.

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 it involves facts, opinions, 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, and whether explicit comprehension instruction affects these relationships 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.

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Table 1
Item, Strategy, Domain, and Structural Means and Standard Deviations for Middle School Students' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=532).

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.20, 0.75	1.37, 0.79	1.45, 0.70	4.01, 1.50	
2	1.76, 0.51	1.10, 0.85	1.49, 0.71	4.35, 1.35	
3	1.22, 0.70	1.16, 0.60	0.96, 0.94	3.34, 1.35	Science Reading
4	1.52, 0.62	1.42, 0.69	1.69, 0.59	4.63, 1.28	25.67, 5.04
5	1.17, 0.86	1.60, 0.65	1.79, 0.54	4.56, 1.40	
6	1.58, 0.64	1.52, 0.65	1.69, 0.62	4.79, 1.33	
7	1.42, 0.72	0.83, 0.56	1.14, 0.78	3.39, 1.29	
8	1.28, 0.79	1.41, 0.79	1.23, 0.75	3.93, 1.52	Science Text
9	1.55, 0.68	1.45, 0.78	1.45, 0.70	4.44, 1.55	15.54, 3.57
10	1.50, 0.76	1.26, 0.77	1.02, 0.91	3.78, 1.53	
11	1.16, 0.58	0.98, 0.53	1.29, 0.78	3.43, 1.15	
12	1.57, 0.65	1.34, 0.66	1.43, 0.71	4.34, 1.30	
13	1.63, 0.63	1.43, 0.71	1.58, 0.68	4.63, 1.24	
14	1.48, 0.68	1.43, 0.62	1.57, 0.72	4.49, 1.29	
15	1.07, 0.97	1.49, 0.80	1.47, 0.71	4.17, 1.64	Science Reading
16	1.46, 0.82	1.53, 0.71	1.55, 0.68	4.46, 1.47	Strategies
17	1.22, 0.63	1.57, 0.72	1.26, 0.85	4.05, 1.48	45.54, 9.05
18	1.20, 0.76	0.79, 0.86	1.35, 0.79	3.34, 1.57	
19	1.48, 0.79	1.12, 0.65	1.52, 0.70	4.12, 1.40	
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		General Awareness 86.75, 15.78

Table 2

Item, Strategy, Domain, and and Structural Component Means and Standard Deviations for Grade 4 Students' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=113)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.20, 0.76	1.29, 0.87	1.40, 0.77	3.89, 1.58	
2	1.77, 0.55	1.13, 0.84	1.33, 0.98	4.23, 1.44	
3	1.08, 0.70	1.29, 0.58	0.90, 0.76	3.27, 1.33	Science Reading
4	1.36, 0.60	1.39, 0.69	1.75, 0.47	4.50, 1.21	25.44, 5.24
5	1.17, 0.82	1.58, 0.68	1.73, 0.60	4.48, 1.43	
6	1.78, 0.48	1.57, 0.55	1.72, 0.62	5.06, 1.13	
7	1.25, 0.77	0.67, 0.59	1.15, 0.76	3.07, 1.19	
8	1.28, 0.78	1.50, 0.77	1.12, 0.76	3.89, 1.46	Science Text
9	1.64, 0.60	1.42, 0.81	1.45, 0.67	4.51, 1.52	15.01, 3.23
10	1.33, 0.82	1.27, 0.74	0.94, 0.93	3.53, 1.55	
11	1.12, 0.52	0.87, 0.56	1.37, 0.80	3.36, 1.15	
12	1.57, 0.58	1.27, 0.64	1.47, 0.71	4.31, 1.27	
13	1.59, 0.70	1.31, 0.76	1.59, 0.68	4.51, 1.52	
14	1.50, 0.67	1.49, 0.60	1.57, 0.67	4.55, 1.15	
15	1.67, 0.63	0.98, 0.97	1.46, 0.81	4.12, 1.50	Science Reading
16	1.44, 0.74	1.45, 0.83	1.55, 0.69	4.44, 1.56	Strategies
17	1.21, 0.67	1.59, 0.68	1.34, 0.85	3.53, 1.55	44.32, 8.77
18	0.95, 0.81	0.65, 0.85	1.27, 0.87	2.86, 1.78	
19	1.47, 0.77	1.03, 0.70	1.46, 0.69	3.96, 1.43	
20	1.50, 0.76	1.03, 0.63	1.73, 0.58	4.27, 1.20	
21	1.15, 0.82	1.01, 0.82	1.66, 0.54	3.82, 1.58	
Domain Means, S.D.	29.04, 5.43	25.92, 5.94	29.44, 5.78		General Awareness 84, 77, 15.25

Table 3
Item, Strategy, Domain,and Structural Components Means and Standard Deviations for Grade 5 Students' Metacognitive Knowledge about Science Reading, Science Text,and Science Reading Strategies (N=108)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.22, 0.77	1.36, 0.78	1.54, 0.66	4.12, 1.37	
2	1.82, 0.49	1.07, 0.85	1.47, 0.73	4.37, 1.29	
3	1.31, 0.61	1.15, 0.56	0.96, 0.96	3.43, 1.35	Science Reading
4	1.54, 0.57	1.44, 0.65	1.77, 0.54	4.74, 1.17	26.08, 3.98
5	1.17, 0.83	1.56, 0.67	1.81, 0.48	4.54, 1.29	
6	1.64, 0.65	1.47, 0.69	1.78, 0.55	4.89, 1.33	
7	1.47, 0.69	0.91, 0.60	1.05, 0.80	3.43, 1.37	
8	1.19, 0.84	1.40, 0.80	1.23, 0.76	3.82, 1.55	Science Text
9	1.56, 0.67	1.46, 0.73	1.40, 0.68	4.42, 1.40	15.31, 3.32
10	1.40, 0.78	1.20, 0.77	1.05, 0.91	3.65, 1.52	
11	1.23, 0.56	0.98, 0.51	1.36, 0.75	3.57, 1.00	
12	1.60, 0.64	1.39, 0.58	1.43, 0.69	4.42, 1.31	
13	1.68, 0.56	1.28, 0.78	1.68, 0.59	4.64, 1.16	
14	1.55, 0.62	1.43, 0.58	1.52, 0.72	4.49, 1.28	
15	1.73, 0.57	0.87, 0.98	1.50, 0.81	4.10, 1.50	Science Reading
16	1.45, 0.69	1.31, 0.90	1.52, 0.70	4.29, 1.45	Strategies
17	1.20, 0.61	1.60, 0.74	1.29, 0.88	4.09, 1.47	45.39,7.91
18	1.14, 0.79	0.67, 0.83	1.41, 0.75	3.21, 1.44	
19	1.37, 0.85	1.12, 0.67	1.51, 0.66	4.00, 1.33	
20	1.38, 0.84	1.04, 0.61	1.78, 0.54	4.19, 1.26	
21	1.51, 0.70	1.27. 0.69	1.60, 0.65	4.38, 1.30	
Domain Means, S.D.	30.18, 4.38	26.21, 5.23	30.55, 5.51		General Awareness 86.79, 13.12

Table 4
Item, Strategy, Domain, and Structural Component Means and Standard Deviations for Grade 6 Students' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=109)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.28, 0.72	1.35, 0.81	1.46, 0.69	4.09, 1.52	
2	1.81, 0.42	1.13, 0.86	1.59, 0.67	4.53, 1.41	
3	1.26, 0.71	1.16, 0.58	0.84, 0.93	3.26, 1.31	Science Reading
4	1.54, 0.63	1.51, 0.68	1.77, 0.54	4.83, 1.18	26.22, 5.43
5	1.21, 0.87	1.75, 0.53	1.78, 0.57	4.74, 1.46	
6	1.57, 0.61	1.53, 0.63	1.68, 0.65	4.78, 1.39	
7	1.57, 0.63	0.83, 0.59	1.17, 0.80	3.56, 1.38	
8	1.43, 0.71	1.57, 0.70	1.26, 0.70	4.26, 1.46	Science Text
9	1.64, 0.63	1.61, 0.65	1.46, 0.70	4.72, 1.52	16.57, 3.77
10	1.56, 0.73	1.37, 0.78	1.11, 0.94	4.04, 1.51	
11	1.18, 0.60	1.02, 0.51	1.32, 0.74	3.52, 1.14	
12	1.64, 0.60	1.44, 0.66	1.49, 0.70	4.57, 1.24	
13	1.56, 0.67	1.54, 0.64	1.61, 0.67	4.71, 1.24	
14	1.39, 0.72	1.50, 0.62	1.67, 0.67	4.56, 1.40	
15	1.74, 0.58	1.10, 0.97	1.56, 0.78	4.40, 1.51	Science Reading
16	1.60, 0.65	1.37, 0.88	1.64, 0.65	4.61, 1.50	Strategies
17	1.19, 0.65	1.65, 0.69	1.16, 0.87	4.00, 1.54	47.06, 8.86
18	1.34, 0.67	0.90, 0.86	1.38, 0.78	3.61, 1.45	
19	1.52, 0.78	1.18, 0.60	1.61, 0.67	4.32, 1.36	
20	1.46, 0.82	1.20, 0.69	1.65, 0.61	4.31, 1.28	
21	1.51, 0.74	1.21, 0.72	1.72, 0.56	4.44, 1.40	
Domain Means, S.D.	31.01, 5.61	28.23, 6.16	30.71, 6.42		General Awareness 89.84, 16.38

Table 5
Item, Strategy, Domain, and Structural Components Means and Standard Deviations for Grade 7 Students' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading (N=93)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.13, 0.76	1.41, 0.78	1.46, 0.70	4.00, 1.55	
2	1.69, 0.49	1.17, 0.86	1.49, 0.72	4.35, 1.36	
3	1.24, 0.70	1.17, 0.58	0.94, 0.94	3.44, 1.38	Science Reading
4	1.61, 0.57	1.53, 0.62	1.61, 0.66	4.75, 1.40	25.80, 5.08
5	1.15, 0.87	1.70, 0.55	1.83, 0.48	4.68, 1.30	
6	1.44, 0.68	1.52, 0.70	1.71, 0.56	4.67, 1.35	
7	1.34, 0.76	0.84, 0.45	1.28, 0.71	3.46, 1.67	
8	1.38, 0.74	1.34, 0.77	1.39, 0.69	4.11, 1.38	Science Text
9	1.57, 0.63	1.56, 0.73	1.52, 0.69	4.65, 1.49	16.22, 3.65
10	1.57, 0.76	1.28, 0.81	1.15, 0.91	4.00, 1.56	
11	1.16, 0.60	0.99, 0.50	1.33, 0.77	3.48, 1.24	
12	1.66, 0.60	1.35, 0.69	1.56, 0.58	4.57, 1.25	
13	1.73, 0.55	1.47, 0.64	1.67, 0.65	4.87, 1.12	
14	1.56, 0.65	1.34, 0.65	1.62, 0.72	4.53, 1.31	
15	1.60, 0.72	1.11, 0.98	1.65, 0.67	4.35, 1.67	Science Reading
16	1.44, 0.71	1.69, 0.66	1.53, 0.75	4.66, 1.49	Strategies
17	1.22, 0.55	1.62, 0.67	1.27, 0.82	4.11, 1.35	47.40, 9.84
18	1.39, 0.68	0.84, 0.89	1.46, 0.75	3.69, 1.50	
19	1.54, 0.77	1.15, 0.59	1.63, 0.67	4.32, 1.37	
20	1.47, 0.80	1.23, 0.66	1.61, 0.66	4.31, 1.36	
21	1.57, 0.73	1.28, 0.76	1.66, 0.58	4.51, 1.31	
Domain Means, S.D.	30.45, 5.86	27.88, 5.92	31.28, 6.70		General Awareness 89.41, 17.02

Table 6
Item, Strategy, Domain, and Structural Component Means and Standard Deviations for Grade 8 Students' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=109)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.13, 0.75	1.45, 0.67	1.38, 0.69	3.96, 1.46	
2	1.67, 0.58	1.01, 0.87	1.58, 0.66	4.28, 1.26	
3	1.21, 0.75	1.02, 0.68	1.16, 0.87	3.39, 1.41	Science Reading
4	1.57, 0.70	1.24, 0.77	1.55, 0.70	4.36, 1.41	24.86, 5.30
5	1.14, 0.90	1.42, 0.75	1.81, 0.55	4.37, 1.49	
6	1.45, 0.71	1.50, 0.70	1.57, 0.69	4.51, 1.39	
7	1.47, 0.71	0.91, 0.50	1.09, 0.82	3.47, 1.29	
8	1.15, 0.86	1.25, 0.85	1.17, 0.81	3.57, 1.67	Science Text
9	1.32, 0.79	1.20, 0.88	1.43, 0.77	3.95, 1.72	14.71, 3.59
10	1.64, 0.66	1.19, 0.75	0.88, 0.86	3.72, 1.48	
11	1.08, 0.63	1.04, 0.56	1.07, 0.78	3.19, 1.19	
12	1.39, 0.79	1.24, 0.72	1.23, 0.79	3.85, 1.33	
13	1.59, 0.63	1.54, 0.66	1.36, 0.78	4.49, 1.37	
14	1.44, 0.74	1.39, 0.62	1.47, 0.80	4.30, 1.29	
15	1.35, 0.85	1.28, 0.92	1.28, 0.86	3.91, 1.79	Science Reading
16	1.40, 0.75	1.53, 0.74	1.41, 0.74	4.35, 1.33	Strategies
17	1.26, 0.67	1.38, 0.80	1.26, 0.81	3.89, 1.52	43.84, 9.51
18	1.23, 0.74	0.91, 0.84	1.24, 0.80	3.38, 1.53	
19	1.51, 0.77	1.13, 0.68	1.41, 0.80	4.06, 1.48	
20	1.46, 0.78	1.25, 0.68	1.51, 0.73	4.22, 1.45	
21	1.27, 0.86	1.37, 0.73	1.58, 0.68	4.21, 1.51	
Domain Means, S.D.	28.72, 6.04	26.14, 5.32	28.14, 6.69		General Awareness 83.41, 16.32

Table 7
Item, Strategy, Domain, and Structural Component Means and Standard Deviations for Male Students' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=271)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.16, 0.74	1.35, 0.80	1.36, 0.75	3.87, 1.54	
2	1.71, 0.54	1.07, 0.84	1.51, 0.70	4.29, 1.33	
3	1.17, 0.75	1.13, 0.64	0.96, 0.92	3.27, 1.43	Science Reading
4	1.46, 0.66	1.40, 0.71	1.64, 0.63	4.50, 1.28	24.75, 5.22
5	1.04, 0.87	1.50, 0.71	[illegible].61	4.28, 1.50	
6	1.49, 0.69	1.44, 0.69	1.60, 0.66	4.53, 1.41	
7	1.41, 0.72	0.86, 0.59	1.13, 0.78	3.40, 1.34	
8	1.24, 0.82	1.36, 0.82	1.24, 0.76	3.85, 1.61	Science Text
9	1.48, 0.73	1.35, 0.82	1.36, 0.74	4.19, 1.62	15.14, 3.82
10	1.47, 0.79	1.20, 0.79	1.04, 0.91	3.70, 1.52	
11	1.20, 0.62	0.94, 0.57	1.22, 0.78	3.37, 1.22	
12	1.60, 0.65	1.33, 0.71	1.42, 0.71	4.35, 1.34	
13	1.61 ,0.65	1.39, 0.73	1.54, 0.71	4.54, 1.30	
14	1.42, 0.72	1.40, 0.63	1.50, 0.75	4.32, 1.32	
15	1.48, 0.77	0.94, 0.96	1.39, 0.84	3.81, 1.66	Science Reading
16	1.39, 0.76	1.41, 0.83	1.43, 0.72	4.24, 1.53	Strategies
17	1.16, 0.66	1.46, 0.77	1.23, 0.84	3.85, 1.50	44.03, 9.50
18	1.20, 0.76	0.83, 0.86	1.36, 0.81	3.38, 1.61	
19	1.44, 0.81	1.09, 0.64	1.46, 0.74	3.99, 1.44	
20	1.45, 0.80	1.12, 0.68	1.57, 0.71	4.14, 1.34	
21	1.31, 0.82	1.17, 0.76	1.57, 0.68	4.06, 1.46	
Domain Means, S.D.	28.92, 5.83	25.86, 6.08	29.00, 6.65		General Awareness 83.92, 16.57

Table 8
Item, Strategy, Domain, and Structural Component Means and Standard Deviations for Female Students' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=261)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.23. 0.77	1.39, 0.77	1.55, 0.65	4.16, 1.44	
2	1.80, 0.47	1.14, 0.87	1.47, 0.72	4.41, 1.38	
3	1.26, 0.63	1.18, 0.56	0.96, 0.96	3.41, 1.27	Science Reading
4	1.58, 0.57	1.44, 0.67	1.75, 0.55	4.77, 1.27	26.64, 4.67
5	1.29, 0.83	1.70, 0.57	1.85, 0.44	4.84, 1.23	
6	1.67, 0.57	1.59, 0.61	1.78, 0.56	5.05, 1.19	
7	1.43, 0.72	0.80, 0.52	1.16, 0.79	3.39, 1.24	
8	1.33, 0.77	1.47, 0.75	1.21, 0.74	4.01, 1.42	Science Text
9	1.61, 0.61	1.56, 0.71	1.54, 0.65	4.71, 1.43	15.95, 3.24
10	1.52, 0.73	1.33, 0.74	1.00, 0.92	3.85, 1.54	
11	1.11, 0.53	1.01, 0.48	1.37, 0.76	3.48, 1.06	
12	1.55, 0.66	1.35, 0.61	1.44, 0.70	4.38, 1.26	
13	1.64, 0.61	1.47, 0.69	1.62, 0.65	4.73, 1.18	
14	1.54, 0.63	1.47, 0.60	1.64, 0.67	4.65, 1.22	
15	1.76, 0.57	1.20, 0.97	1.59, 0.75	4.54, 1.53	Science Reading
16	1.54, 0.65	1.52, 0.81	1.63, 0.68	4.70, 1.36	Strategies
17	1.28, 0.60	1.67, 0.65	1.30, 0.86	4.25, 1.43	47.10, 8.30
18	1.21, 0.75	0.75, 0.86	1.33, 0.78	3.29, 1.54	
19	1.53, 0.76	1.15, 0.66	1.58, 0.66	4.26, 1.34	
20	1.46, 0.81	1.17, 0.64	1.75, 0.53	4.38, 1.26	
21	1.48, 0.74	1.28, 0.74	1.72, 0.51	4.48, 1.39	
Domain Means, S.D.	30.82, 5.05	27.85, 5.28	30.99, 5.74		General Awareness 89.70, 14.37

Table 9
Item, Strategy, Domain, and Structural Component Means and Standard Deviations for Low Ability Readers' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=91)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.02, 0.79	1.19, 0.80	1.26, 0.81	3.47, 1.62	
2	1.64, 0.62	1.00, 0.85	1.36, 0.78	3.99, 1.42	
3	1.16, 0.79	1.13, 0.67	0.92, 0.90	3.22, 1.35	Science Reading
4	1.33, 0.58	1.21, 0.75	1.58, 0.65	4.12, 1.36	23.07, 5.03
5	1.00, 0.83	1.43, 0.76	1.64, 0.66	4.07, 1.55	
6	1.49, 0.77	1.26, 0.66	1.44, 0.81	4.20, 1.55	
7	1.41, 0.70	0.75, 0.59	1.03, 0.77	3.19, 1.41	
8	1.24, 0.79	1.47, 0.77	1.03, 0.81	3.75, 1.62	Science Text
9	1.41, 0.76	1.22, 0.85	1.22, 0.70	3.85, 1.48	14.53, 3.59
10	1.48, 0.78	1.21, 0.81	1.05, 0.94	3.75, 1.67	
11	0.99, 0.61	0.85, 0.61	1.18, 0.82	3.01, 1.20	
12	1.52, 0.64	1.15, 0.67	1.33, 0.78	4.00, 1.26	
13	1.36, 0.74	1.22, 0.79	1.37, 0.83	3.96, 1.42	
14	1.22, 0.80	1.37, 0.66	1.48, 0.75	4.08, 1.23	
15	1.43, 0.80	0.88, 0.95	1.36, 0.86	3.67, 1.61	Science Reading
16	1.18, 0.78	1.27, 0.84	1.32, 0.74	3.77, 1.36	Strategies
17	1.22, 0.61	1.46, 0.75	1.27, 0.80	3.96, 1.32	40.33, 7.28
18	1.08, 0.81	0.67, 0.84	1.22, 0.87	2.97, 1.39	
19	1.32, 0.80	0.93, 0.70	1.23, 0.78	3.48, 1.42	
20	1.18, 0.84	0.96, 0.71	1.62, 0.68	3.75, 1.33	
21	1.26, 0.83	0.90, 0.76	1.53, 0.66	3.69, 1.36	
Domain Means, S.D.	26.93, 5.31	23.89, 5.17	27.20, 5.81		General Awareness 77.92, 13.59

Table 10
Item, Strategy, Domain, and Structural Component Means and Standard Deviations for Average Ability Readers' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=282)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.23, 0.73	1.39, 0.78	1.48, 0.69	4.09, 1.48	
2	1.74, 0.52	1.06, 0.84	1.49, 0.72	4.28, 1.30	
3	1.26, 0.69	1.11, 0.62	0.96, 0.94	3.33, 1.36	Science Reading
4	1.51, 0.65	1.37, 0.69	1.66, 0.62	4.55, 1.28	25.56, 4.88
5	1.17, 0.87	1.55, 0.68	1.81, 0.53	4.53, 1.38	
6	1.59, 0.63	1.49, 0.67	1.71, 0.60	4.78, 1.29	
7	1.40, 0.73	0.79, 0.55	1.15, 0.80	3.34, 1.28	
8	1.20, 0.82	1.38, 0.79	1.17, 0.75	3.74, 1.51	Science Text
9	1.49, 0.69	1.39, 0.79	1.45, 0.72	4.33, 1.56	15.08, 3.44
10	1.48, 0.77	1.24, 0.79	0.94, 0.89	3.67, 1.45	
11	1.18, 0.60	0.98, 0.50	1.22, 0.78	3.38, 1.14	
12	1.56, 0.67	1.35, 0.66	1.38, 0.72	4.29, 1.30	
13	1.66, 0.61	1.48, 0.67	1.54, 0.71	4.67, 1.20	
14	1.49, 0.67	1.39, 0.61	1.47, 0.76	4.35, 1.29	
15	1.59, 0.71	1.02, 0.98	1.40, 0.83	4.01, 1.66	Science Reading
16	1.44, 0.71	1.46, 0.83	1.48, 0.74	4.38, 1.43	Strategies
17	1.18, 0.64	1.50, 0.77	1.20, 0 88	3.88, 1.54	44.62, 8.62
18	1.16, 0.74	0.77, 0.84	1.27, 0.81	3.20, 1.60	
19	1.48, 0.80	1.10, 0.66	1.50, 0.72	4.07, 1.40	
20	1.46, 0.80	1.15, 0.65	1.62, 0.65	4.23, 1.25	
21	1.32, 0.81	1.22, 0.75	1.63, 0.63	4.17, 1.47	
Domain Means, S.D.	29.56, 5.17	26.28, 5.53	29.20, 6.14		General Awareness 85.26, 14.93

Table 11
Item, Strategy, Domain, and Structural Component Means and Standard Deviations for Above Average Ability Readers' Metacognitive Knowledge about Science Reading, Science Text, and Science Reading Strategies (N=159)

Factor	Declarative Mean, S.D.	Procedural Mean, S.D.	Conditional Mean, S.D.	Strategy Mean, S.D.	Structural Component Mean, S.D.
1	1.24, 0.76	1.44, 0.77	1.50, 0.65	4.18, 1.39	
2	1.85, 0.39	1.25, 0.86	1.57, 0.65	4.67, 1.35	
3	1.18, 0.64	1.25, 0.53	0.97, 0.98	3.41, 1.35	Science Reading
4	1.64, 0.55	1.62, 0.60	1.82, 0.46	5.08, 1.09	27.36, 4.67
5	1.26, 0.84	1.77, 0.46	1.85, 0.47	4.89, 1.25	
6	1.62, 0.57	1.72, 0.56	1.80, 0.49	5.14, 1.12	
7	1.47, 0.72	0.94, 0.54	1.20, 0.76	3.61, 1.21	
8	1.47, 0.72	1.44, 0.78	1.44, 0.66	4.35, 1.41	Science Text
9	1.72, 0.56	1.69, 0.63	1.58, 0.65	4.99, 1.41	16.94, 3.40
10	1.53, 0.73	1.33, 0.71	1.13, 0.93	3.99, 1.57	
11	1.21, 0.50	1.06, 0.52	1.48, 0.71	3.75, 1.03	
12	1.62, 0.62	1.43, 0.64	1.57, 0.61	4.62, 1.28	
13	1.73, 0.56	1.45, 0.71	1.77, 0.47	4.95, 1.05	
14	1.62, 0.58	1.55, 0.58	1.79, 0.56	4.96, 1.17	
15	1.79, 0.54	1.25, 0.94	1.70, 0.64	4.74, 1.46	Science Reading
16	1.68, 0.59	1.58, 0.77	1.74, 0.57	5.00, 1.41	Strategies
17	1.28, 0.64	1.75, 0.56	1.37, 0.81	4.40, 1.40	50.14, 8.65
18	1.35, 0.74	0.89, 0.89	1.55, 0.67	3.79, 1.53	
19	1.58, 0.75	1.26, 0.58	1.74, 0.56	4.58, 1.23	
20	1.61, 0.73	1.25, 0.62	1.75, 0.56	4.61, 1.30	
21	1.61, 0.68	1.42, 0.68	1.72, 0.53	4.75, 1.29	
Domain Means, S.D.	32.05, 5.34	29.52, 5.48	32.96, 5.70		General Awareness 94.44, 15.07

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

Science Reading

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

3. 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.

4. 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.

5. 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.

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

Science Text

7. 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.

8. 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.

9. 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.

10. 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.

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

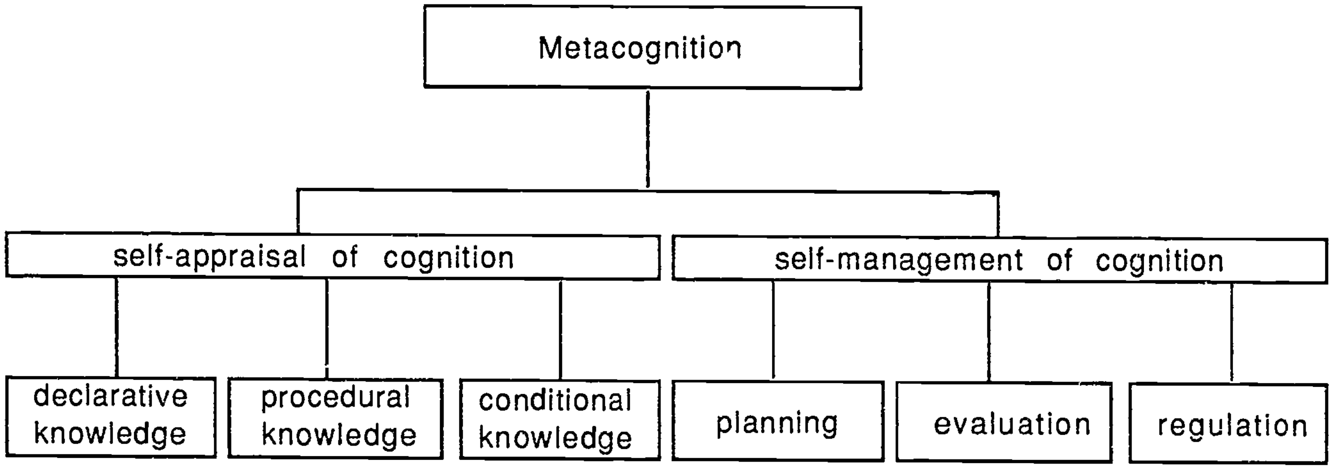

Figure 2. Metacognition (Adapted from Jacobs and Paris, 1987).

The desired image of an efficient successful reader of science text is a person who is able to realize that the text is not an absolute truth and that all science writing is a form of interpretation and, at least to some extend, all science writing may be a distortion or simplification of information and ideas that have been developed or recorded through the processes of science (strategy 8).

Declarative Test Item

Text in science books is:
- a) sometimes hard to believe (score 1)
- b) someone's view of what is true (score 2)
- c) always true because it is about science (score 0)
- d) ________________________ (scored individually)

Procedural Test Item

When you read science text you should:
- a) accept as true everything you read (score 0)
- b) accept the text as true if it matches your beliefs (score 1)
- c) remember that the text is someone's view of what is true (score 2)
- d) ________________________ (scored individually)

Conditional Test Item

You should realize text in science books is someone's view of what is true because:
- a) it makes reading easier (score 0)
- b) otherwise you may think the text represents absolute truth (score 2)
- c) it may not be what you think is true (score 1)
- d) ________________________ (scored individually)

Declarative Interview Question

Should you believe everything you read in your science text? Why? (Why not?) (scored individually)

Procedural Interview Question

How would knowing that text in science books is someone's view of what is true affect how you read science text? (scored individually)

Conditional Interview Question

If your experiment's results do not agree with your science text, what would you do? Why? (scored individually)

Figure 3: Examples of Test Items and Interview Questions Associated with Specific Strategic Awareness Factors

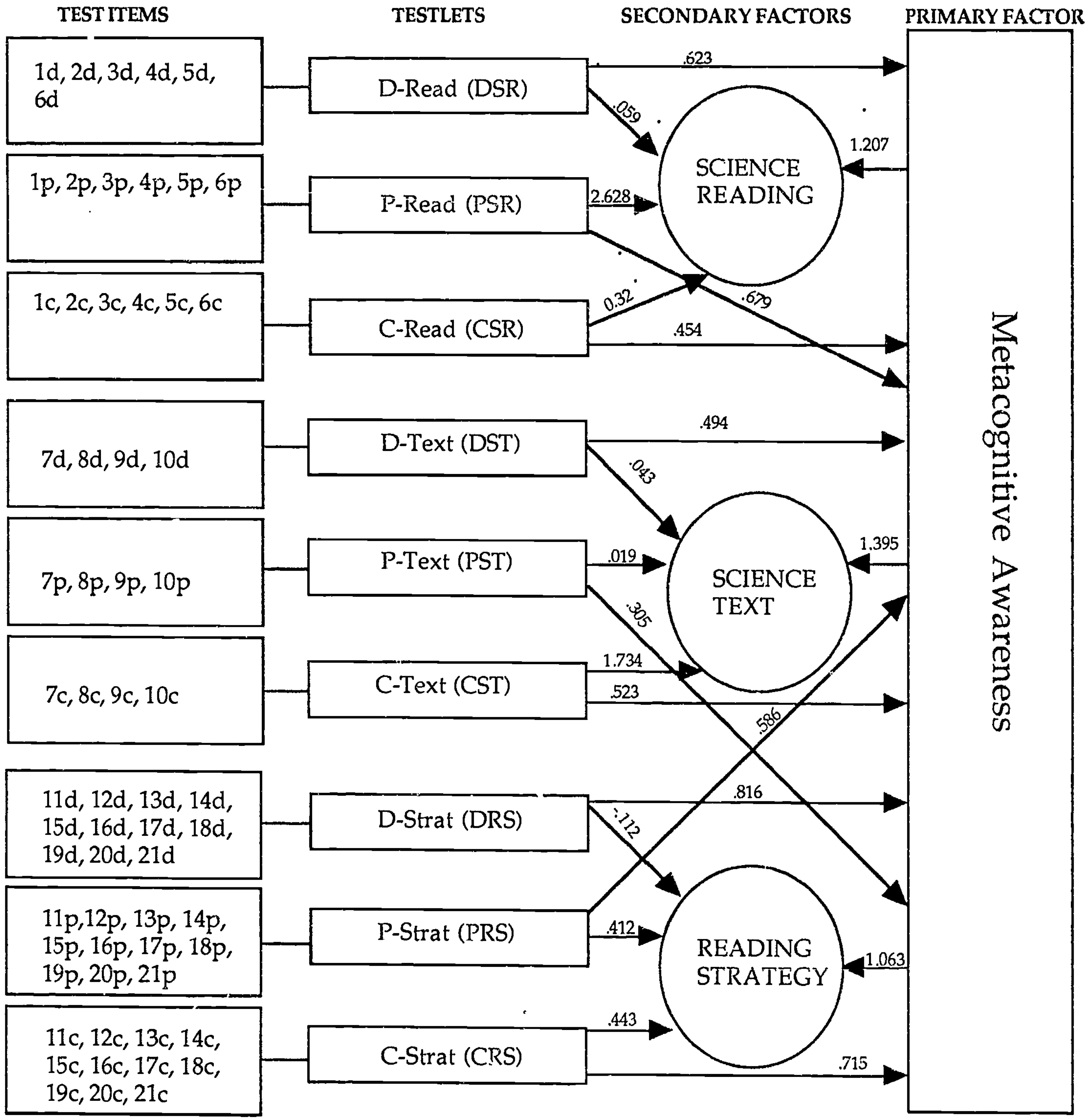

Figure 4. LISREL-7 Model of the Middle School Efficient, Successful Science Readers' Metacognitive Knowledge About Science Reading, Science Text and Science Reading Strategies.