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ABSTRACT

Many educators have long assumed that reading ability is directly related to science achievement, that reading plays a major role in science instruction, and that direct instruction on science reading skills would improve science achievement. The pilot study reported here investigated whether an instructional strategy could be designed to overcome initial differences in reading ability of elementary school students. The results indicate that general reading vocabulary and reading comprehension make a significant difference in science achievement and in the ability to read science textbooks. It is suggested that since classroom teachers have little influence on the structure, organization, and content of science textbooks, that instructional strategies should be developed that supplement existing textbooks and facilitate the learning process. These strategies should include reading as a source of knowledge. (TW)

ABSTRACT

A PRELIMINARY EXPLORATION OF GRADE FIVE STUDENTS' SCIENCE ACHIEVEMENT AND ABILITY TO READ SCIENCE TEXTBOOKS AS A FUNCTION OF GENDER, READING VOCABULARY AND READING COMPREHENSION

Many educators have long assumed that reading ability was directly related to science achievement, that reading plays a major role in science instruction, and that direct instruction on science reading skills would improve science achievement (Corey, 1977; Wright, 1982; Guthrie, 1983; Mayer, 1983; Dempster, 1984; Gabel, 1984; Williams and Yore, 1985). Furthermore the interactive-constructive reading model would suggest that prior concrete experiences would establish a schema, access prior knowledge and reveal knowledge voids, and focus questions for future reading, thus improving the reading comprehension. One can then suggest that a science instructional strategy that initiates learning with concrete experience, supplemented with textual materials, and mediated with direct instruction on critical science reading skills would discount initial differences in general reading vocabulary and general reading comprehension (Esler & Anderson, 1981; Barrow, Kristo & Andrew, 1984; Guerra, 1984; Fisher & Fisher, 1985).

Based on this background the present pilot study investigated whether an instructional strategy could be designed to

overcome initial differences in reading ability of elementary school students. The following questions were explored:

1. Does specific reading vocabulary by reading comprehension interaction exist within the instructional strategy?
2. Can predicted science achievement and science reading differences due to initial reading vocabulary and reading comprehension differences be overcome by a well-designed instructional strategy?
3. Are there gender differences in science achievement and science reading within specific reading vocabulary and reading comprehension levels?
4. Are there interactions of gender and reading ability within the instructional strategy?

The results appear to indicate that general reading vocabulary and reading comprehension make a significant difference in science achievement and in the ability to read science text. Furthermore, the variances observed in boys make the significant contributions to these effects. Little differences in science achievement and science reading ability were related to girls' general reading vocabulary and reading comprehension abilities.

The motivation for this pilot study was the desire to develop an instructional strategy supported by research and theory that would allow elementary teachers to effectively utilize existing science textbooks with a wide variety of students. Classroom teachers have little influence on the structure, organization, and content of science textbooks; and educational research is slow to influence educational publishers. Therefore, the practical solution for the present is to develop instructional strategies that supplement existing textbooks and facilitate the learning process that includes reading as a source of knowledge. Furthermore, research that has a greater probability of being applied by classroom teachers must, utilize information about the learners, instructional materials and teaching skills that for the most part are readily available. A survey of local schools indicated that information was generally available on students' IQ, basic skills and reading abilities. Secondly, most schools have textbooks that require limited ancillary equipment. Thirdly, most teachers are reasonably knowledgeable and skillful at teaching developmental reading and less comfortable with teaching science.

A PRELIMINARY EXPLORATION OF GRADE FIVE STUDENTS' SCIENCE ACHIEVEMENT AND ABILITY TO READ SCIENCE TEXTBOOKS AS A FUNCTION OF GENDER, READING VOCABULARY, AND READING COMPREHENSION

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INTRODUCTION

The acceptance that reading is a widely used teaching/learning strategy in elementary school science instruction has renewed interest in the relationship between science and reading (Carney, 1984; Gabel, 1984; Guerra, 1984). This renewed interest, a desire to move beyond readability formulas (Holliday, 1986), and an attempt to utilize an interactive model of reading (Yore and Shymansky, 1985) require the re-examination of several research issues in the current educational setting (Yore, 1986). This pilot study explored the relationships of gender and general reading ability to science achievement and science reading skills within a common instructional strategy.

BACKGROUND

Many educators have long assumed that reading ability was directly related to science achievement, that reading plays a major role in science instruction, and that direct instruction on science reading skills would improve science achievement (Corey, 1977; Wright, 1982; Guthrie, 1983; Mayer, 1983; Dempster, 1984; Gabel, 1984; Williams and Yore, 1985). Furthermore the interactive-constructive reading model would suggest that prior concrete experiences would establish a schema, access prior skills. They believed that the lack of such reading instruction may explain the less than desirable science achievement patterns of North American children. Williams and Yore (1985) suggested that direct instruction in science reading skills may be the only way to overcome the increasing gap between readers' abilities and reading demands of science textbooks. The continued writing of science textbooks to readability formulas has limited the science curriculum and the continued reliance on other subject areas to teach the needed content reading skills is foolhardy. Yore (1986) suggests that science language is unique and requires unique reading skills best understood by science teachers and is most effectively learned by utilizing actual science textual materials. Bean, Singer, and Cowan (1985) suggest study guides utilizing analogies may improve reading comprehension and science achievement. Graphic overviews, concept maps, word webs, and chapter outlines are other ways to improve general understanding in science (Barrow, et al., 1984; Thelen, 1984).

Mayer (1983) pointed out that exposure of students to relevant science content does not ensure mastery of that content. Finley (1983) found that students recalled different ideas when exposed to the same textual materials, students appeared to utilize a constructive approach while reading, and students did not appear to have a common schema of the central concept. Several researchers found that girls outperform boys in early reading achievement (Quorn & Yore, 1978; Chall, 1983), while numerous science assessments have indicated that boys outperform girls in science achievement by the time of early grade 4 (Hobbs, Boldt, Erickson, Quelch & Sieben, 1979; Taylor, 1982). Williams and Yore (1985) implied that this may be a result of boys' improved science reading ability as noted in grades 4, 5 and 6. It also may be that the grade level content reading and achievement pattern in elementary school is due to the fact that girls' general reading abilities are discounted by the lack of prior science knowledge and previous concrete science experience on which to base their reading comprehension.

Based on this background the present pilot study investigated whether an instructional strategy could be designed to overcome initial differences in reading ability of elementary school students. The following questions were explored:

1. Does specific reading vocabulary by reading comprehension interaction exist within the instructional strategy?
2. Can predicted science achievement and science reading differences due to initial reading vocabulary and reading comprehension differences be overcome by a well designed instructional strategy?
3. Are there gender differences in science achievement and science reading within specific reading vocabulary and reading comprehension levels?
4. Are there interactions of gender and reading ability within the instructional strategy?

DESIGN

A one-group posttest only design was developed for this study. The design was:

$$S - O_v - O_c - X - O_s - O_r$$

An intact sample (S) was selected. The sample was administered a popular general reading test that measured reading vocabulary (O_v) and reading comprehension (O_c). The sample was split into two manageable random groups and provided instruction (X) on a specific science topic. Upon completion of the instruction, science achievement (O_s) and science reading ability (O_r) were measured.

Sample

Fifty-four grade 5 students from a suburban, mixed ethnic, English-speaking, middle-class school near Victoria, British Columbia, were selected as the sample. The sample was composed of 27 girls and 27 boys. The girls' ages ranged from 10 years to 11 years 1 month, with an average age of 10 years 7 months. The boys' ages ranged from 10 years to 12 years, with an average age of 10 years 11 months.

General Reading Ability

The Gates-MacGinitie (1965) Survey D Form 1 was used to assess general reading vocabulary and reading comprehension abilities. This instrument was administered using standardized procedures to the whole sample two months before the instructional component started.

Reading Vocabulary. A 50-item test that required students to identify a word of similar meaning to another word was used to measure students' general reading vocabulary. Student scores were converted into grade-level scores using the translation table provided.

Reading Comprehension. The students' ability to read complete prose passages with understanding was defined as general reading comprehension. The student was required to fill-in 52 blanks in 21 written passages with an appropriate word. The number of correct responses was converted into a grade-level score using the conversion tables provided.

Instructional Treatment

An activity-centered instructional strategy supplemented with reading, content reading activities, and study skills was based on Chapter 4: Light of the grade 5 Exploring Science program (Blecha, Buegger, Gega, Green & Weid, 1977). The topic and science program were selected because the sample had limited prior exposure to the topic and textbook series. Also, the text materials were judged to be at or near appropriate readability level. Three randomly selected 100-word passages from the beginning, middle, and end of the chapter yielded an average Fry readability level of grade 4 (Yore, 1979).

Eleven lessons were developed and taught over five and one-half weeks by the investigator, dealing with characteristics of light, refraction, reflection, colors, pigments, filters, human eye, vision, and optical illusions. Table 1 illustrates the lessons, topic, activities, and homework involved in this science unit.

{INSERT TABLE 1}

Lessons generally consisted of an introduction, experience, discussion, and supplemental homework (Yore & Quorn, 1983). Introductions attempted to motivate students, provide lesson

Table 1

Outline of the Light Unit

Lesson	Topic	Activity	Homework
1	Informal Reading Inventory	Group Inventory (Yore, 1984, pp. 19-21)	None
2	Unit Overview and Opening	Demonstration of optical phenomena and related lights' characteristics. Discussion of parts of textbook.	None
3	How Light Travels	Experiment on straight line promulgation. Discussion of how to make a content outline.	Read pp. 146-149 (Blecha, et al., 1977)
4	Shadows	Demonstration of shadows.	None
5	Refraction	Experiments on refraction.	Prepare outline of discussion
6	Refraction and Lenses	Review Lessons 2 to 5 and experiment on lenses.	Read pp. 150-153 (Blecha, et al., (1977); Prepare outline
7	Reflection from Plane Mirrors	Experiment with plane mirrors and Mirror Cards (ESS, 1973). Discussion of applications of lenses and mirrors.	Read pp. 154-157 (Blecha, et al., 1977); Prepare outline
8	Reflection from Curved Mirrors	Experiment with curved mirrors.	Finding Hidden Clues (Yore, 1984, p. 42)
9	Colors of Light, Filters and Pigments	Experiment with pigments and filters and selective transmission and absorption.	Read pp. 158-167 (Blecha, et al., 1977); Prepare outline; Identifying Signal Words (Yore, 1984, p. 43)
10	The Human Eye and Vision	Demonstration of pinhole viewer. Discussion of the human eye.	Read pp. 168-177 (Blecha, et al., (1977); Prepare outline; Interpreting Pictures and Diagrams (Yore, 1984, p. 45)
11	Optical Illusions and Unit Review	Demonstration of and experience with optical illusions.	Read pp. 178-188 (Blecha, et al., (1977); Review outlines. Complete unit overview (Yore, 1984, p. 41)

focus, establish procedures, and considered safety and behavior. Experiences attempted to provide students with primary data by means of concrete hands-on activities or viewing a demonstration. The discussion phase of the lesson provided students with an intellectual scaffold to help process their experiences and formulate the desired concept or skill. Teacher questioning encouraged students to systematically share, translate, organize, analyze, synthesize, verify, and apply their knowledge. Supplemental homework including reading assignments was used to reinforce and enrich ideas previously explored and discussed in class or to develop a specific content reading skill. Specific content reading skills appropriate to the textual materials used were assigned as homework. These content reading activities included a group informal reading inventory, outlining, finding hidden clues, identifying signal words, and interpreting pictures and diagrams specifically designed for the Exploring Science program (Yore, 1984).

Science Achievement

Science achievement was measured by a teacher-made test consisting of 32 items. The items required recall or application of knowledge to fill in the blank and provide short answers. The test was submitted to other science educators to assess the relation between stated instructional objectives and test items. It was judged to assess recall and application level science achievement and fairly assess the stated objectives for the Light unit.

Reliability was measured by the KR-20 method (Tuckman, 1978).

The KR-20 analysis of individual items yielded a reliability index of 0.88. Inspection of individual item responses indicated that all items were correctly answered by someone and no items were correctly answered by everyone. The item analysis yielded difficulty indices from 0.06 to 0.85 and discrimination indices from 0.11 to 0.63.

Science Reading Ability

Science reading ability was measured by a 16-item short answer teacher-made test designed to assess students' knowledge of the science textbook's organization, the application of referents to establish meaning, and the application of signal words to determine the type of logical statements or arguments being made. The test items used science content related to light and optics but were different from that used in the content reading activities.

The test was submitted to elementary reading teachers to judge the face validity. The panel of teachers believed the test measured the content reading skills identified. Reliability was determined by the KR-20 method. The KR-20 analysis yielded a reliability index of 0.64. Inspection of item responses indicated that all items were correctly answered by someone and no item was correctly answered by everyone. An item analysis indicated difficulty indices from 0.13 to 0.83 and discrimination indices from 0.07 to 0.41.

ANALYSIS OF DATA AND RESULTS

Individual student data on general reading vocabulary, general reading comprehension, science achievement, and science reading ability were correlated to illustrate any potential patterns. Significant ($p<0.05$) correlations between these variables were found ($0.25 \leq r \leq 0.51$). The highest correlation was found between reading vocabulary and science achievement ($r = 0.51$). Reading comprehension and science reading ability was the second highest correlation ($r = 0.35$).

Individual students were categorized by sex and their general reading abilities as being equal to and below grade level (grade level $\leq$ 5.9) or above grade level (grade level > 5.9). Descriptive data are provided in Tables 2, 3 and 4 for science achievement and in Tables 5, 6 and 7 for science reading skills.

{INSERT TABLES 2-7}

These data were analyzed by a series of two-way and one-way analyses of variance. Gender, vocabulary level, and comprehension level were used as the main dimensions on the two-way ANOVAs. Secondly, one-way ANOVAs were conducted on the science achievement and science reading data for girls and boys separately.

The reading vocabulary by reading comprehension ANOVA of science achievement data yielded $p = 0.49$ ($F = 0.49$, df 1,50) interaction effect, $p = 0.01$ ($F = 6.42$, df 1,50) reading vocabulary effect, and $p = 0.09$ ($F = 2.99$, df 1,50) reading comprehension effect. The reading vocabulary by reading comprehension ANOVA of science reading data yield $p = 0.07$ ($F = 3.25$, df 1,50) interaction effect, $p = 0.48$ ($F = 0.50$, df 1,50) reading vocabulary effect, and $p = 0.00$ ($F = 9.51$, df 1,50) reading comprehension effect.

Table 2

Means, Science Achievement and Cell Sizes for Specific Reading Comprehension and Reading Vocabulary Abilities

Reading Comprehension	Reading Vocabulary At or below Grade Level (≤ 5.9)	Above Grade Level (> 5.9)
At or Below Grade Level (< 5.9)	$\bar{x} = 8.80$ n = 10	$\bar{x} = 13.83$ n = 6
Above Grade Level (> 5.9)	$\bar{x} = 15.09$ n = 11	$\bar{x} = 17.37$ n = 27

Table 3

Science Achievement Means and Cell Sizes for Specific Genders and Reading Vocabulary Abilities

Gender	Reading Vocabulary At or Below Grade Level (≤ 5.9)	Above Grade Level (> 5.9)
Girls	$\bar{x} = 13.50$ n = 8	$\bar{x} = 16.26$ n = 19
Boys	$\bar{x} = 7.88$ n = 8	$\bar{x} = 17.16$ n = 19

Table 4

Science Achievement Means and Cell Sizes for Specific Genders and Reading Comprehension Abilities

Gender	Reading Comprehension At or below Grade Level ($\leq$ 5.9)	Reading Comprehension Above Grade Level (> 5.9)
Girls	$\bar{x}$ = 14.00 n = 9	$\bar{x}$ = 16.17 n = 18
Boys	$\bar{x}$ = 10.67 n = 12	$\bar{x}$ = 17.40 n = 15

Table 5

Science Reading Means and Cell Sizes for Specific Reading Comprehension and Reading Vocabulary Abilities

Reading Comprehension	Reading Vocabulary At or Below Grade Level ($\leq$ 5.9)	Reading Vocabulary Above Grade Level (> 5.9)
At or Below Grade Level	$\bar{x}$ = 6.40 n = 10	$\bar{x}$ = 10.67 n = 6
Above Grade level	$\bar{x}$ = 8.36 n = 11	$\bar{x}$ = 9.74 n = 27

Table 6

Science Reading Means and Cell Sizes for Specific Genders And Reading Vocabulary Abilities

Gender	Reading Vocabulary At or Below Grade Level ($\leq$ 5.9)	Reading Vocabulary Above Grade Level (> 5.9)
Girls	$\bar{x}$ = 9.75 n = 8	$\bar{x}$ = 9.89 n = 19
Boys	$\bar{x}$ = 6.25 n = 8	$\bar{x}$ = 8.79 n = 19

Table 7

Science Reading Means and Cell Sizes for Specific Genders and Reading Comprehension Abilities

Gender	Reading Comprehension At or Below Grade level ($\leq$ 5.9)	Reading Comprehension Above Grade Level (> 5.9)
Girls	$\bar{x}$ = 9.33 n = 9	$\bar{x}$ = 10.11 n = 18
Boys	$\bar{x}$ = 6.00 n = 12	$\bar{x}$ = 9.67 n = 15

The gender by reading vocabulary ANOVA of science achievement data yielded p = 0.09 (F = 3.08, df 1,50) two-way interaction, p = 0.54 (F = 0.37, df 1,50) gender effect, and p = 0.00 (F = 10.50, df 1,50) vocabulary effect. The gender by reading comprehension ANOVA of science achievement data yielded p = 0.22 (F = 1.54, df 1,50) two-way interaction, p = 0.77 (F = 0.09, df 1,50) gender effect, and p = 0.02 (F = 6.17, df 1,50) comprehension effect. Analysis of the science achievement data for each sex separately yielded p = 0.32 (F = 1.03, df 1,25) vocabulary effect for girls and p = 0.00 (F = 13.51, df 1,25) vocabulary effect for boys. The second set of analyses yielded p = 0.42 (F = 0.66, df 1,25) comprehension effect for girls and p = 0.01 (F = 7.00, df 1,25) comprehension effect for boys on the science achievement data.

The sex by reading vocabulary ANOVA of science reading data yielded p = 0.13 (F = 2.32, df 1,50) two-way interaction, p = 0.02 (F = 6.39, df 1,50) gender effect, and p = 0.09 (F = 2.91, df 1,50) vocabulary effect. The sex by reading comprehension ANOVA of science reading data yielded p = 0.04 (F = 4.53, df 1,50) two-way interaction, p = 0.02 (F = 5.57, df 1,50) gender effect, and p = 0.00 (F = 11.49, df 1,50) comprehension effect. Analysis of these data for each sex separately yielded p = 0.89 (F = 0.02, df 1,25) vocabulary effect for the girls, p = 0.05 (F = 4.39, df 1,25) vocabulary effect for the boys, p = 0.43 (F = 0.66, df 1,25) comprehension effect for the girls, and p = 0.00, (F = 14.61, df 1,25) comprehension effect for the boys on the science reading data.

These results appear to indicate that general reading vocabulary and reading comprehension make a significant difference in science achievement and in the ability to read science text. Furthermore, the variances observed in boys make the significant contributions to these effects. Little differences in science achievement and science reading ability were related to girls' general reading vocabulary and reading comprehension abilities.

DISCUSSION

The motivation for this pilot study was the desire to develop an instructional strategy supported by research and theory that would allow elementary teachers to effectively utilize existing science textbooks with a wide variety of students. Classroom teachers have little influence on the structure, organization, and content of science textbooks; and educational research is slow to influence educational publishers. Therefore the practical solution for the present is to develop instructional strategies that supplement existing textbooks and facilitate the learning process that includes reading as a source of knowledge. Furthermore, research that has a greater probability of being applied by classroom teachers must utilize information about the learners, instructional materials, and teaching skills that for the most part are readily available. A survey of local schools indic ed that information was generally available on students' IQ, basic skills, and reading abilities. Secondly, most schools have textbooks that require limited ancillary equipment. Thirdly, most teachers are reasonably knowledgeable and skillful at teaching developmental reading and less comfortable with teaching science.

The lack of significant ($p < 0.05$) vocabulary by comprehension interactions on science achievement and science reading appears to indicate that both of these component abilities are independent requisites to effective science learning within the presecribed instructional strategy. Well-developed vocabulary skills do not compensate for poorly developed comprehension skills. Likewise, well-developed comprehension skills do not compensate for less well-developed vocabulary skills.

The significant results related to reading ability confirm earlier findings. These results are not surprising since most reading tests contain a sizable measure of general intelligence. Lawson, Nordland, and Kahle (1975) found large significant correlations between a specific reading test and cognitive development. Others report similar correlations for reading tests and measures of IQ. Therefore most existing reading tests add little information about learners not contained in measures of IQ or cognitive development. It is somewhat optimistic to assume that differences in general ability would be remediated in five to six weeks of instruction.

The interesting results occur when one looks at the two separate measures of reading ability. Reading vocabulary appears to indicate general knowledge or working memory. Mayer (1983) stresses the importance of working memory on meaningful learning. Prior knowledge that is accessed and related to a specific problem is a critical cognitive influence on comprehension. Reading comprehension results appear to indicate that it is related to the technical skills of reading. Although this reading test did not assess science reading skills, it does provide a general indication of that dimension. Significant gender effects were found in the science reading where girls outperformed boys. The one significant interaction occurred between gender and reading comprehension and is difficult to interpret at this time.

The one-way ANOVA on science achievement and science reading for separate sexes suggested that the achievement effects related to conceptual schema and were mainly a female phenomena and the science reading effects were mainly a male phenomena. These results appear to indicate that girls need greater emphasis on experiential science while boys need emphasis on science reading skills.

IMPLICATIONS FOR FUTURE RESEARCH

Research on science teaching/learning involving science textbooks requires an eclectic instructional psychology and learning paradigm. Neither a cognitive development, hierarchical learning or receptive learning model will be sufficient to guide this research. Science education research must consider the works of cognitive scientists, linguists, and reading researchers when investigating the science learning involving science textbooks. Mayer (1983) partially outlines the significant considerations related to meaningful learning. He draws freely from a variety of psycho-philosophical theories. A purist's point-of-view will limit a researcher interested in science instruction related to science textbooks. The work of Ausbel, Bransford, Vygotsky and the University of Illinois Center for the Study of Reading are a few promising sources. Furthermore, research on science learning involving textbooks does not involve expositive prose in isolation. Science textbooks are not intended to be used in an experiential vacuum. Effective science teaching/learning involves numerous influences and factors, such as accessible prior knowledge (working memory), general intellectual ability, general reading ability, and science specific reading skills.

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