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ABSTRACT

This paper presents the results of a comparison of the effects of gender on fourth-grade students' learning in hands-on science. This study is part of a 3-year classroom based project of hands-on science in 6 urban and 2 suburban classrooms (n=171). Half of the teachers used a supported-inquiry approach, and half used activity-based science to teach a hands-on science unit on electricity over a 6 week period, each completing 12 learning experiences. Both approaches engaged students in hands-on exploration. Teachers participated in a 1-day training session, followed by two after-school coaching sessions. A written electricity test was used as a pre and posttest. A diagram analysis exam was used as a posttest only (both instruments are in the appendix). There were no gender effects on the pretest, posttests, and assessment modality. (Contains 15 references.) (PR)

EQUAL OPPORTUNITY LEARNING: HANDS-ON SCIENCE FOR GIRLS AND BOYS*

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Introduction

Inquiry-based science instruction is receiving renewed attention because it fosters higher order thinking and can potentially benefit ALL students, including those considered at risk (Educating Americans for the 21st Century, National Science Board Commission, 1983). In addition to racial/ethnic minorities, women are included as an at-risk population in the NAEP report cards on science achievement (NAEP, 1988). As a group, girls have a more negative attitude toward science than boys, fewer girls than boys study science in school, and girls' achievement on standardized tests of higher-level science skill is considerably less than boys (Mullis & Jenkins, 1988). Additionally, low percentages of women pursue careers in science- and technology-related fields (Sjoberg & Imsen, 1988).

Currently, researchers are examining sociocultural factors that may contribute to the disparity in science performance between girls and boys. For example, in most cultures, science is defined in masculine terms. In one study when asked to draw-a-scientist, only 28 of 4,807 students drew a woman (Chambers, 1983). Additionally, differences have been found in the amounts and kinds of informal experiences boys and girls have with science, and in the treatment and interactions of girls and boys in the classroom.

Several studies provide evidence that young girls have different and fewer out-of-school experiences with scientific phenomena, and that these are just as important for student learning as more formal school experiences (Kahle & Lakes, 1983). Based on interviews with twelfth-grade students to determine the knowledge base they used to answer questions on a standardized science achievement test, Erickson & Farkas (1991) found that females referred more to school-based experiences, while males referred more to out-of-school experiences to explain their answers. The achievement of boys on this measure exceeded that of girls. The authors concluded that boys are able to apply the science knowledge they attain from out-of-school experiences to a broader range of tasks than girls who draw upon predominately school experiences.

Differential treatment by teachers and the ways that boys and girls interact and participate in the science classroom have also been shown to contribute to gender differences in performance and interest in science. One explanation for the differential treatment by teachers is their perception that boys have stronger scientific abilities than girls. In one study, Shepardson & Pizzini (1992), found that teacher bias resulted in their inclination to ask boys more open-ended questions, such as analyzing data and explaining results, and to ask girls more factual questions, such as experimental procedures and observations. Observations of high school science classes (Jones & Wheatly, 1989; Haggarty, 1987) revealed that males tend to manipulate the equipment more during labs while the females watch. These authors suggest that this pattern of performance reflects males' perceptions that 'doing' science means hands-on exploration of scientific problems and questions, and females' preceptions that 'doing' science means finding the right answers. Males are also more likely to attempt responses to questions even when they are unsure of the answer, enabling the teacher to prompt and guide them to a more accurate response. In cntrast, females tend to take fewer risks in volunteering answers if they are unsure about its "correctness" (Haggarty, 1991). As a result, fewer girls than boys actively participate in and demonstrate science activities and experiments (Kahle, 1988).

Purpose and Questions

This paper presents the results of a comparison of the effect of gender on fourth-grade students' learning in hands-on science . The study is part of a three-year classroom based project of hands-on science in six urban and two suburban fourth-grade classrooms (Dalton, Morocco, Tivnan, & Rawson, in press; Morocco, Dalton, Tivnan & Rawson, 1992). The project compared two hands-on approaches to teaching electricity -- supported inquiry science and activity-based science -- in six urban and two suburban classrooms over a two month period. Results of the original study clearly demonstrated that hands-on science benefited student' learning, and that the supported inquiry approach was particularly beneficial. Of particular interest was the fact that hands-on science was effective for students with and without learning disabilites, low and high achieving students, and urban and suburban students. The positive results for these learners considered 'at risk' in science suggested that these approaches to hands-on science might also benefit girls. Both approaches include features identified in previous research on programs that are successful in encouraging girls in science, such as engaging girls in hands-on activities, allowing them to become full partners in the discovery process (rather than observers or recorders) and putting them in charge of their learning (Ellis, 1992; Frederickson & Nicholson, 1991; Kahle, 1985). The following questions guide the current analysis:

What effect does gender have on fourth-grade students' learning in a hands-on electricity unit?

Does the effect vary as a function of students' gender and level of domain knowledge after instruction?

Does the effect of the assessment modality vary as a function of students' gender and level of domain knowledge after instruction?

Method

Overview of procedure Six urban and two suburban teachers in the metropolitan Boston area participated in this study. Half the teachers used a supported-inquiry approach, and half used activity-based science to teach a hands-on science unit on electricity over a 6 week period, completing 12 learning experiences. Both approaches engaged students in hands-on exploration. Teachers participated in a 1-day training session, followed by 2 after-school coaching sessions.

Research staff visited each class weekly to provide technical assistance and support. While the two approaches to hands-on science differed in several key respects, both approaches focussed on engaging students in hands-on exploration. Typically, teachers introduced the lesson to the class, had students work together in same-gender pairs to carry out the experiments, and then gathered the class together again to share results.

Students. 171 fourth-grade students in six urban and two suburban classrooms participated in this study, including 81 girls (see Tables 1 and 2). To test effects on students with different levels of domain specific knowledge, we constructed a composite electricity knowledge score based on post-instruction performance on a written questionnaire and diagram test and classified students as high achieving (top third), average achieving (middle third) or low achieving (bottom third).

Assessment measures and scoring. Two forms of alternative assessment were used to assess students' understanding and application of electricity concepts: a written questionnaire requiring students to write and, in some cases, draw their responses to open ended questions, and a diagram analysis test requiring students to construct a response based on their analysis of figural information (see Appendix A). All students were administered the written questionnaire before and after treatment. The diagram test was administered after treatment only.

We developed and piloted the instruments, scoring criteria and scoring procedures in Year 2 and then fieldtested a revised version in Year 3 (see Figures 1 and 2). Internal test reliability is strong (Cronbach's alpha coefficient = .75 on the pre-questionnaire, .86 on the post-questionnaire and .67 on the diagram test). After training, six independent raters evaluated the quality of students' responses on the questionnaire and diagram tests, assigning each item a score from 1 (a naive, or egocentric response) to 4 (an elaborated correct response). Twenty-five percent of the tests were scored by two raters to assess inter-rater reliability. The median percent agreement was .74 on the pre-questionnaire, .69 on the post-questionnaire and .88 on the diagram test. Correlations on the total scores given by the 2 raters were .91 on the pre-questionnaire, .93 on the post-questionnaire and .94 on the diagram test.

Analysis and Key Findings

Analyses of variance were used to compare students' performance on the pre-post questionnaire and diagram post-tests. In addition to assessing overall growth, we analyzed performance in relation to four key concepts (simple, series, and parallel circuits, and conductivity). Key finding are listed below and illustrated in Figures 3 and 4:

- Prior to instruction, girls and boys had comparable levels of electricity knowledge on the written questionnaire($F(1,170)=.01$; $p<.941$)

- After instruction, girls and boys demonstrated comparable levels of growth in their understanding and application of electricity concepts on the written questionnaire ($F(1,170)=.34$; $p<.562$). They also performed comparably on the constructed diagram post-test ($F(1,170)=2.52$; $p<.115$)

- Analysis of electricity concept scores were consistent with the overall results. Girls performed comparably to boys on even the most difficult concepts, such as parallel circuits.

- Girls and boys obtained higher scores on the constructed diagram test than on the questionnaire. The effect of the assessment modality did not differ by gender ($F(1,170)=.00$; $p<.997$).

- Girls, as well as boys, were a diverse science learning group, including low, average and high achieving science learners. There was no interaction effect for gender and domain knowledge after instruction.($F(2,164)=2.1$; $p<.125$).

Conclusions

The lack of any gender effects offers additional support to the argument that challenging, hands-on science can successfully engage girls in science and lead them to achieve as well as their male counterparts, even in the traditionally masculine domain of electricity.

The study raises interesting questions for further study. In addition to the shared features identified in other research as promising for girls' learning in science, these classrooms used same-gender partners for the hands-on component of each learning experience. Given the reliance on mixed-gender groups in many science classrooms today, it would be useful to investigate whether the gender composition or the size of the grouping had a differential effect on girls versus boys. Also, while this study assessed student learning, it did not examine whether girls and boys arrived at that learning in different ways. It may be that there are important differences in girls' and boys' approaches to hands-on science and problem solving that will contribute to our understanding of how best to teach science.

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1. Imagine you have a battery, a bulb and some wire.

    1a. First, draw a large diagram of the bulb, showing all the different parts. Label each part of the bulb.

    1b. Second, add the battery and wire to your diagram, showing one way to light the bulb. Label all the parts you know.

    1c. Describe what happens to make your bulb light up.

    1d. What could you do to make the bulb burn brighter?

    1e. What would happen if you added another bulb to your set-up?

2a. What is an electrical 'conductor'?

    2b. Give an example.

3a. What is an electrical 'insulator'?

    3b. Give an example.

4. If you want to test whether a dime conducts electricity, what could you do? You may draw to help explain your answer.

5. Carlos and Sue tried to light a bulb with a battery and some wire, but it didn't work.

    5a. What could be the problem? (list as many problems as you can)

    5b. How would you check it?

6. Sue had a string of tree lights. She unscrewed 1 bulb and <u>all the lights went out</u>.

    6a. Why?

    6b. Draw a large diagram to show how the bulbs could be wired in the circuit.

7. Marcos had a different string of lights. When he unscrewed one bulb, the <u>rest of the lights stayed on.</u>

    7a. Why?

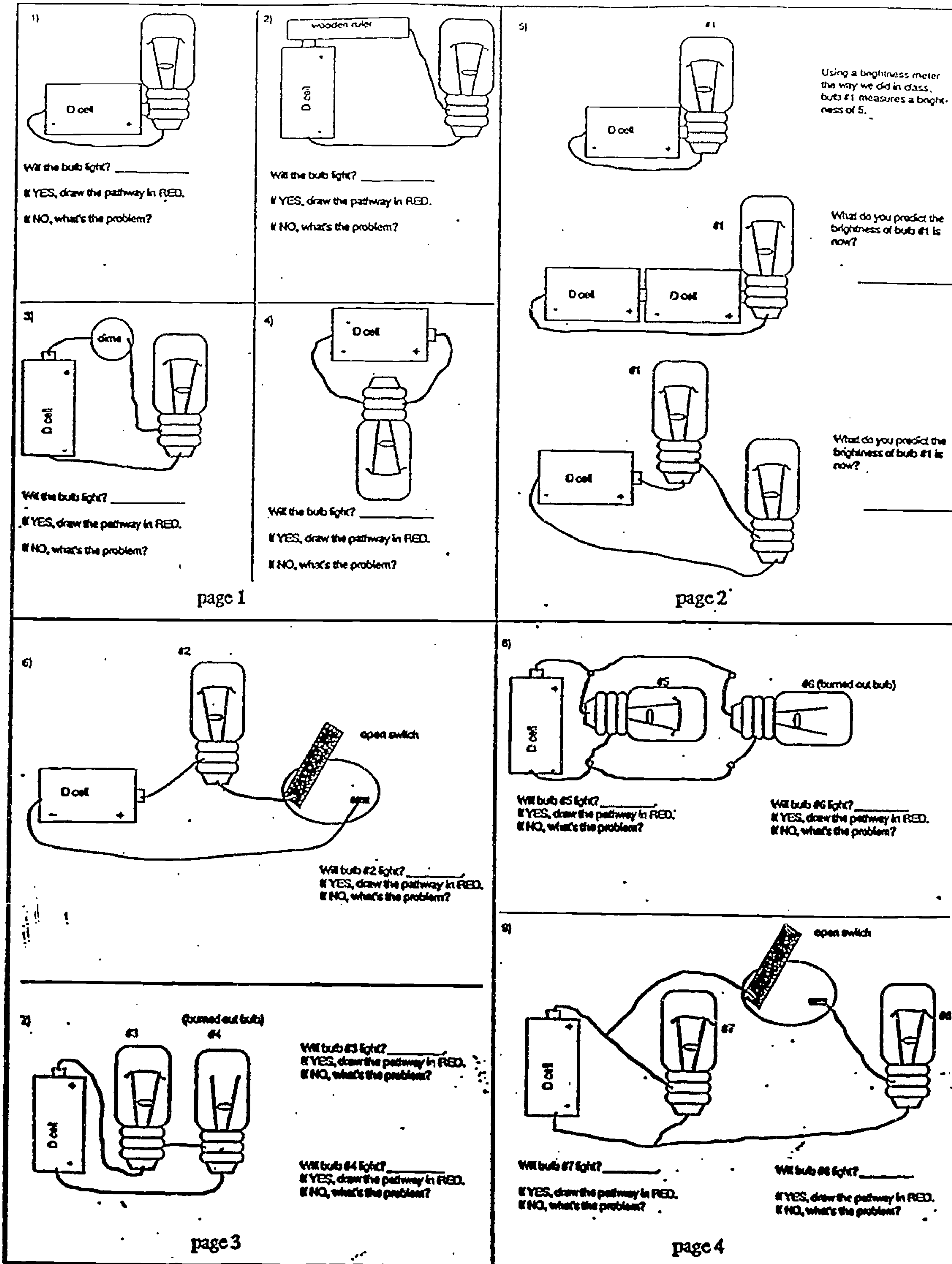
    7b. Draw a large diagram to show how the bulbs could be wired in this circuit.

8. Why is a switch an important part of an electric circuit?

Concept Scores:

Simple circuit = questions 1a and 1b
Conductivity = questions 2a, 2b, and 4
Series circuit = questions 6a and 6b
Parallel circuit = questions 7a and 7b

Appendix A-1. Pre/post written questionnaire items.



Appendix A-2. Diagram analysis post test.

TABLE 1
Student Sample

		Level of Post-Instruction Domain Knowledge		
		Low	*Average*	*High*
Gender	*Girls n=81*	23 (28%)	25 (30%)	33 (41%)
	Boys n=90	31 (34%)	34 (38%)	25 (28%)

TABLE 2
Background Characteristics of 4th-grade Girls and Boys

	Girls (n=81)	Boys (n=90)
CA (months)		
Mean	117	119
(SD)	(5.2)	(6.6)
Ethnicity (percent)		
White	60	66
African American	27	22
Latino	9	7
Other	4	5
Percent ESL	14	25
Percent Urban	64	73
Achievement (percentiles)[1]		
Spelling mean	56	53
(SD)	(28)	(28)
Range	1-99	1-99
Math mean	48	43
(SD)	(26)	(27)
Range	10-99	1-99

1. WRAT-R administered prior to instruction

GENERAL SCORING CRITERIA

Level 0: No response, responds with "I don't know," or provides an unscorable response.

Level 1: A naive or descriptive answer that is egocentric, irrelevant or repeats the question.

Level 2: A response that is incorrect or ignorant of the concepts (2A) or one that shows a clear confusion between two concepts—misconception (2B).

Level 3: A generally good response, which may contain an inaccuracy, provide only a partial explanation or omit one of the examples called for.

Level 4: A complete and accurate response.

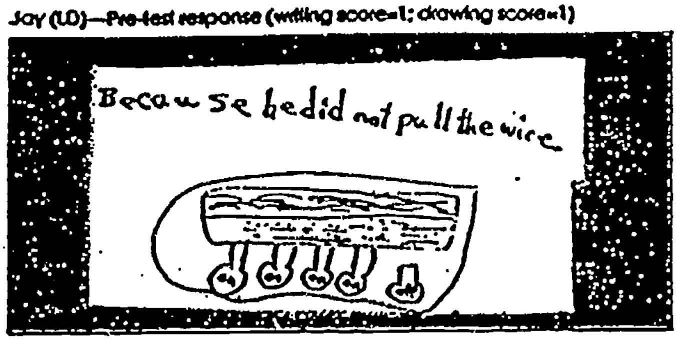
EXAMPLE OF ONE LD STUDENT'S GROWTH IN PARALLEL CIRCUITS

7. Marcos had a different string of lights. When he unscrewed one bulb, the rest of the lights stayed on.

7a. Why?

7B. Draw a LARGE diagram to show how the bulbs could be wired in this circuit.

Jay (LD)—Pre-test response (writing score=1; drawing score=1)



Jay (LD)—Post-test response (writing score=3, drawing score =4)

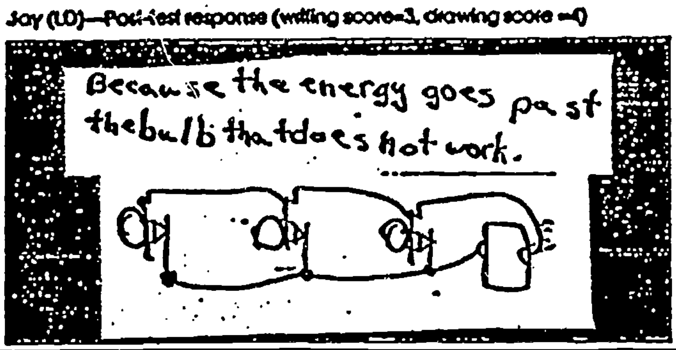


Figure 1. General scoring criteria, with a sample rating of one LD student's responses on a parallel circuit questionnaire item given pre- and post-instruction.

Id. What could you do to make the bulb burn brighter?
(VERSION B--QUESTION 2C)

The purpose of this question is to assess students' understanding of the relationship between bulb brightness and other components in the circuit. To increase the brightness of a bulb in a simple circuit, the amount and/or flow of electric current must be increased. This can be done most easily by increasing the voltage (number of batteries or battery voltage) without increasing the resistance (bulbs, wires).

level 4: Student knows that increasing the voltage will increase the bulb's brightness and also mentions the batteries should be in series or offers more than one option.

- "get a more powerful battery, a brighter bulb, or two batteries"
- "use 2 batteries, one on top of another"

level 3: Student knows that increasing the voltage will increase the bulb's brightness, but does not mention the batteries should be in series or does not offer more than one option OR suggests a less likely solution that potentially could affect the bulb's brightness by manipulating the amount of resistance in the circuit OR gives an incomplete or partially correct response. The correct portion should relate to level 4 responses. The incorrect portion may correspond to level 2 responses.

- "add another battery."
- "get a more powerful battery."
- make the filament smaller
- get a thicker strip of wire
- get more batteries and tie the wire to the part that you plug into the lamp.

level 2: (2A) Student provides an incorrect explanation regarding the relationship between voltage and resistance, applies an irrelevant use of circuit knowledge OR (2B) evidences a misconception (confuses brightness with number of bulbs and not the amount of the energy source OR equates faster light with more powerful light OR equates the tightness of the connection to the level of brightness).

level 2A:
- add another wire
- touch the bottom of the bulb to the battery, but keep the wire wrapped up
- put it in a dark room

level 2B:
- use two bulbs
- you could buy a brighter light bulb
- put the battery on a higher speed of light
- push the wires harder

level 1: Student offers a naive or egocentric response, an irrelevent response not related to circuits, OR relies entirely on experience/knowledge of household electricity

- let it stay on till it burn
- screw it into a lamps socket and turn on the power meaning turn or flick the light switch

level 0: student does not respond, responds "I don't know", or provides an unscorable response.

- if you put a there battery

(although we might infer that sara meant " a there" to mean "another" or "a third" battery, it's too much of a jump in this case to give her credit for understanding the concept)

Figure 2. An example of specific scoring criteria for questionnaire item 2c.

Figure 3

4th-Grade Girls' and Boys' Performance on Pre and Post Measures of Electricity Knowledge

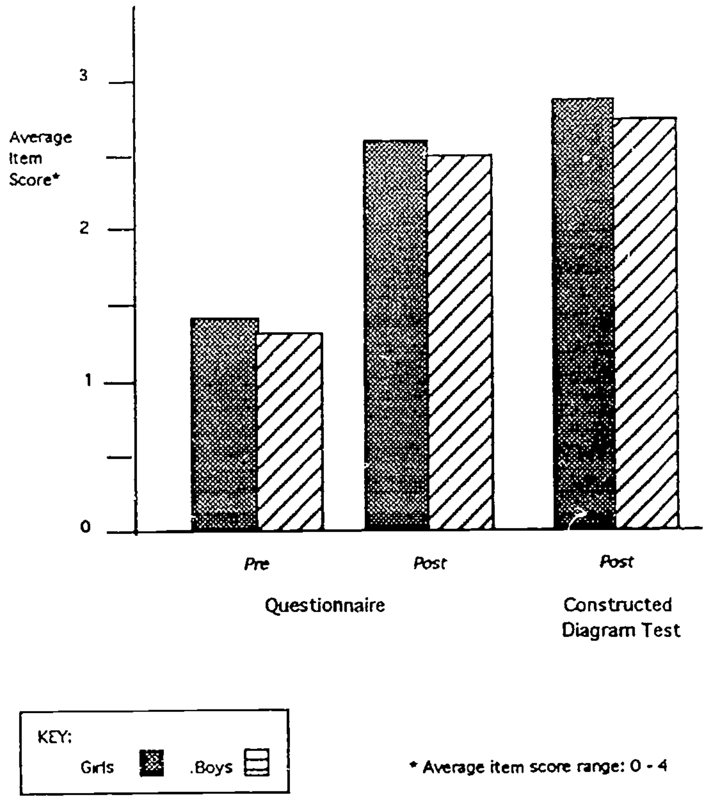


Figure 4

4th-Grade Girls' and Boys' Performance by Level of Domain Knowledge