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ABSTRACT

Two studies were conducted to clarify the influence of experiences and aptitudes on male-female differences in formal thought. Participants were 788 seventh-, ninth-, and eleventh-graders in three school districts differing in location, socioeconomic composition, and course offerings. Formal thought was measured with tasks involving proportional reasoning and predicting displaced volume. The ability to predict displaced volume was measured by an eight item paper-and-pencil test called the Water Glass Puzzle. Subjects' responses were categorized according to four strategies of response derived from protocols for a similar task. To measure proportional reasoning, the Balance Puzzle was used to present 13 problems. Response choices reflected one of four inaccurate strategies or the correct strategy for solving the puzzle. Experience with math and science was assessed in two ways: (1) students indicated how many years of math and science courses they had taken, and (2) the socioeconomic composition of the school (which was related to math and science offerings) was established from principals' reports. Vocabulary, Letter Series, Find a Shape Puzzle, Paper Folding and Water Level tests were used to assess aptitudes. Anticipated male-female differences in formal thought emerged in the data. It is concluded that aptitude measures are not sufficient to explain why males choose accurate strategies more frequently than females do. (Author/RH)

Male-Female Differences in Formal Thought

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That we need to foster scientific literacy is undeniable. That females are less scientifically literate than males is well documented. To create a scientifically literate population, we must understand how science learning takes place and how individuals can be encouraged to continuously update their science knowledge throughout the life span. Formal thought, as defined by Inhelder and Piaget (1958) is an important aspect of scientific literacy. In this paper, we focus on why females develop formal thought more slowly than males during adolescence. We consider two explanations: 1) Different experiences for the sexes, 2) Different aptitudes in the sexes.

Female deficits in scientific literacy limit the participation of females in science policy making. Almond (1950) defines the "attentive public" for science as those who read science news and magazines, attend science events, vote on science-related issues, and participate in science-related interest groups. Thus, this population contributes far more to science policy than suggested by their number in the population. Males comprise a much greater portion of the attentive public for science than females (Miller, Suchner, & Voelker, 1980). Thus, females have less influence on science policy than males do. As suggested by Gilligan (1977), females offer a different perspective on intellectual issues and, thus, deserve equitable representation in policy making. Such equity cannot occur when females lack formal thinking skills required for scientific literacy.

Different Experiences for the Sexes

Efforts to explain male-female differences in formal thought must consider that females' experiences differ from those of males throughout the life span. Adolescents have seen innumerable media depictions of females as being unable to balance checkbooks, being easily confused, and spending their lives seeking a cleaner, brighter wash. Many females describe themselves as math-anxious (e.g., Tobias, 1978), as unable to solve math problems (e.g., Covington & Omelich, 1979), and as "confused" or "unable to reason" about machines (e.g., Linn, 1980b). Those who have observed teachers and classrooms have told us that teachers praise females less than they do males (Brophy & Good, 1970; Stallings & Robertson, 1979; Becker, 1981), that praise is given to males for participation in academic activities, while it is given more randomly to females (Delefes & Jackson, 1972), that females receive more negative feedback for the intellectual quality of their work (Dweck, et al., 1978), that the criticism that females receive is more often for reasons of lack of knowledge or skill than it is for males (Spaulding, Note 1,) that math teachers provide more feedback to males (Dweck & Reppucci, 1973), that math teachers persist longer in guiding male students to correct answers (Becker, 1981), and that teachers initiate verbal contact with male students more often than they do with females (Bean, Note 2; Stallings & Robertson, 1979; Becker, 1981). In addition, in small mixed-sex groups working together to solve problems, males take the leadership roles (Lockheed & Harris, Note 3; Lockheed, Harris, & Finkelstein, Note 4). These studies tell us how teachers behave differentially towards males and females and how classroom dynamics reflect a difference in the roles males and females play in learning situations. Research on formal thought needs to consider the different experiences of males and females and to provide for the possibility that effective learning experiences for males may be ineffective for females.

Females may develop inaccurate strategies more frequently than males because of their different experiences. Evidence for this point comes from assessing 1) consistency of inaccurate strategy usage on individual formal thought tasks, 2) consistency of inaccurate strategy usage across different formal thought tasks, and 3) distribution of inaccurate strategies across males and females. As research by Inhelder and Piaget (1958) suggests, reasoners do develop inaccurate strategies about formal thought tasks. For example, many reasoners inaccurately expect that the weight of a metal cube, not its size, influences how much water it displaces when immersed in water. These reasoners' strategy for predicting displaced volume is based on the weight of the object. Other researchers have identified inaccurate strategy usage on a variety of problems (e.g., Proportions: Siegler, 1976; Karplus, Pulos, & Stage, 1980; Pulleys: Gunstone & White, Note 5; Acceleration: McDermott, Note 6). These researchers have shown that reasoners apply their accurate or inaccurate strategies consistently (e.g., Siegler, 1976; Linn & Swiney, 1981). For example, subjects who predict that displaced volume is dependent on weight, not size, will use weight for all predictions. Thus adolescent reasoners have well established, but often inaccurate, strategies for tasks which measure formal thought.

Different aptitudes.

We considered a variety of predisposing aptitudes both separately and combined in an aptitude model. The rationale for our choices is given in this section.

Many researchers have sought to explain male-female differences in terms of systematic aptitude differences for the sexes (e.g., Maccoby & Jacklin, 1974; Wittig & Petersen 1979). Benbow and Stanley (1980) have suggested a genetic deficit in females to explain inferior math performance. Harris (1980) presumes that females, perhaps innately, lack spatial visualization ability as measured by tests such as Embedded Figures (Witkin, et al., 1977), Horizontality (Pascual-Leone, 1980), or Paper Folding (French, Ekstron and Price, 1963). Other researchers find no male-female differences on measures of Spatial Visualization (e.g., Linn & Pulos, Note 7; Petersen, Note 8; Fennema & Sherman, 1977). A recent article (Boles, 1980) concluded that there was no genetic component in spatial ability. This debate, no doubt will go on.

To determine the effects of Spatial Visualization and general ability on strategy usage for formal thought tasks, we measured General Crystallized Ability, General Fluid Visualization, and Familiar Field. These dimensions reflected Snow et al.'s (Note 9) elaboration of Horn and Cattell's General Crystallized and General Fluid ability with Linn and Kyllonen's (1981) addition of Field Dependence-Independence. We elaborate how these abilities were chosen below.

Horn and Cattell (1966) used adult subjects to identify General Crystallized ability, General Fluid ability and Spatial Visualization. Spatial Visualization was thought to be distinct from, but correlated with, General Crystallized and General Fluid ability. General Crystallized ability (Gc), measured by tests such as Vocabulary, requires retrieval of overlearned information from long-term memory. Gc involves both the availability of the information in long-term memory and the ability to retrieve the information. General Fluid ability (Gf), measured by tests such as Letter Series or Raven's Matrices, (Raven, 1962), required identification of new relationships. Gf involved applications of known rules to new situations and invention of new rules for familiar situations.

Spatial Visualization, proposed by Horn and Cattell, (1966) was related to both General Fluid and General Crystallized ability but distinct from them. Tests requiring mental manipulation of figural material, such as Paper Folding or Paper Form Board, best measure Spatial Visualization. Horn and Cattell thought that this dimension assessed the ability to visualize solutions to problems.

Snow et al. (Note 9) extended the Horn and Cattell model to adolescents by administering 32 tests to 241 seventeen year olds. Snow et al. expected to identify General Fluid, General Crystallized, and Spatial Visualization. Instead, they could <u>not</u> separate General Fluid from Spatial Visualization. They identified what they called General Crytallized (Gc) and General Fluid Visualization (Gfv). Spatial Visualization and General Fluid ability formed a single dimension (Gfv), defined by tests requiring mental manipulation of figural or non-figural material. Since their tests seemed more than adequate to identify all three factors postulated by Horn and Cattell we assume that Gc and Gfv represent Horn and Cattell's three factors for our population.

Linn and Kyllonen (1981) elaborated the ability model for this population by adding measures of Field Dependence-Independence (FDI). They set out to determine whether FDI measured a dimension uniquely different from Gfv and Gc. Their investigation represented the two FDI dimensions identified by Witkin and Goodenough (Note 10). One FDI dimension called cognitive restructuring, was measured by embedded figures and closely resembled Snow's Gfv. The other FDI dimension, perception-of-the-upright, was measured by the Rod and Frame (RFT) test and appeared to differ from Gfv. Linn and Kyllonen (1981) added tests of both aspects of FDI to the measures employed by Snow. They found that the cognitive restructuring tests loaded on the Gfv factor as anticipated. The perception-of-the-upright tests, however, combined with the Weschler Adult Intelligence Scale (WAIS) Picture Completion test to form a dimension they labeled Familiar field (Ff). The Ff dimension was hypothesized to measure strategy selection in familiar situations when competing strategies were available.

The ability model identified for these adolescents differed from Horn and Cattell's formulation. Only General Crystallized ability emerged as anticipated. General Fluid ability could not be separated from Spatial Visualization so General Fluid Visualization was identified. When measures of FDI were added, cognitive restructuring overlapped completely with Gfv but perception-of-the-upright became part of the unique factor labeled Familiar field (Ff). Thus our ability model included Gc, Gfv, and Ff.

TWO RESEARCH STUDIES

To clarify the role of experiences and the role of aptitudes in male-female differences in formal thought we have conducted two research studies (Linn & Pulos, Note 7). We approached these questions by: 1) Selecting several formal thought tasks where males out-perform females; 2) Determining whether accurate or inaccurate strategies were used reliably for each formal thought task; 3) Establishing whether females used different inaccurate strategies from males; 4) Measuring aptitudes such as spatial ability and determining whether differences between males' and females' strategy usage were associated with aptitude differences; 5) Assessing factors likely to be associated with differential experience like science course-taking or School Socioeconomic Status (SES) and determining whether differences between males' and females' strategy usage were associated with these experience differences; 6) Determining whether individuals who develop inaccurate strategies for one task also develop inaccurate strategies for other tasks.

To investigate the importance of specific experiences in male-female differences in formal thought we focused on two formal thought tasks known to be solved by males more frequently than females: Proportional Reasoning and Predicting Displaced Volume. Studies of predicting displaced volume (Linn & Pulos, Note 7) and proportional reasoning (Linn & Pulos, Note 7) are summarized in the following section.

Summary of Research Studies

Subjects

Participants were 788 7th (159 females and 145 males), 9th (77 females and 136 males), and 11th graders (139 females and 122 males) in three districts. The school districts differed in location, socioeconomic status (SES), and course offerings. Location and SES were: (1) lower-middle class semirural; (2) middle class urban; and (3) upper-middle class suburban. Science and math course offerings were directly related to SES: Higher SES districts offered more math and science courses. Since location, SES, and educational offerings covary, school SES effects cannot be attributed to a single factor.

Predicting Displaced Volume. Predicting Displaced Volume was measured by an eight item paper-and-pencil test called the Water Glass Puzzle (Linn & Pulos, Note 7). A sample item is shown in Figure 1. Each item pictured a cylinder half full of water and two metal blocks. The relative size and weight of each block was indicated both in the drawing and in the printed question. Four types of items were used. Each item had either equal or unequal volume and equal or unequal weight. Only the practice item showed equal volume and equal weight.

Instructions were: "All the blocks sink and are completely covered by the water. I took one of the blocks and put it in the water and then took it out. Next, I took the second block, put it in the water, and took it out. Which block made the water go up higher? Block A, Block B, or did both blocks make the water go up the same amount?" After a practice item, subjects had five minutes to respond to eight items. All subjects completed the eight items before the time was up; they did not omit items due to insufficient time. Subjects found the items easy; they appeared to solve without much difficulty.

(Figure 1 about here)

Likely inaccurate strategies for Predicting Displaced Volume were determined from protocols for a similar task (Piaget, 1951a, b) and reported by Inhelder and Piaget (1942). Three inaccurate strategies and the accurate one appeared. Our Predicting Displaced Volume items were designed so that each strategy would be reflected in a different pattern of response (Linn & Pulos, Note 7). Responses of subjects using a strategy different from the four we identified would not be categorizable in our system. The four strategies we studied were:

1) Weight-only strategy. The amount of water displaced by an object immersed in water depends only on the weight of the object.

2) Weight-except-when-equal strategy. The amount of water displaced by an object immersed in water depends on the weight of the object except when two objects weigh the same, the one with the greatest volume displaces the most water.

3) Volume-except-when-equal strategy. The amount of water displaced by an object immersed in water depends on the volume of the object, except when two objects have the same volume, then the one with the greatest weight displaces the most water.

4) Volume only strategy. The amount of water displaced by an object immersed in water depends only on the volume of the object.

Thus, subjects' responses on the Predicting Displaced Volume items indicated whether they consistently followed one of these four strategies; those not following any strategy were identified as well.

Proportional Reasoning. To measure Proportional Reasoning, the Balance Puzzle, illustrated in Figure 2, was used (Linn & Pulos, Note 7). For each of the 13 items, an illustration of a balance beam was presented and the holes at equal intervals on either side of the fulcrum were numbered or lettered to indicate the distance from the fulcrum. Each item had four response choices including the correct one. Two types of items were used: 1) Standard, determining proportions with one weight on each side of the balance, and 2) Complex, computing proportions with two weights on at least one side of the balance. Both types are shown in Figure 2.

(Figure 2 about here)

Response choices reflected one of four inaccurate strategies or the correct strategy. Inaccurate strategies included those identified by Siegler (1976) and those identified by Karplus et al. (1977). A symmetry response, identified during pilot work was also represented. Actual responses for each item were selected during pilot testing; only response choices which were selected by pilot subjects were retained so each inaccurate strategy was not repeated for each item.

The following strategies for the Balance Puzzle were investigated:

1. Weight-only. Answer is based on weight alone. The side of the fulcrum with the most weight will go down; equal weights balance. For complex proportions, the weights on either side of the fulcrum are summed.

2. Distance-only. Response based on distance alone; weight is ignored or equal. (Note, Siegler studied this response only for the case when weight was equal.)

3. Symmetry. The beam balances when weights and distances are symmetric: greater weight and greater distance on the same side of the beam. In these responses heavier weights are further from the fulcrum than lighter weights.

4. Addition of weight and distance. Answer is based on weights and distances. Shorter distance is assumed to require more weight but the amount is determined by adding the distance to the weight. The lighter weight is further from the fulcrum than the heavy weight but the distances are incorrect. For example, if a 5 gram weight is hung at a distance of 6, an additive responder choosing a weight for a distance 4, could choose a 7 gram weight, adding one gram for each unit closer to the beam.

5. Multiplication of weight and distance. Answer is based on a correct ratio. Weight and distance are multiplied to compute the torque on each side of the fulcrum.

Thus subject's responses to standard and complex items could be classified as following one of these strategies.

Experience Measures

Experience with math and science was assessed in two ways: 1) Students indicated how many years of math and science courses they had taken, and 2) The socioeconomic status (SES) of the school was established from principal's reports.

Neither of these measures is particularly precise. Self-reports of course taking are often inaccurate. Although the SES for each school was accurate and no doubt correlated with visits to science centers, ownership of chemistry sets, etc., it gives only a general indication of each student's likely experiences.

Aptitude measures. To assess the role of aptitudes we administered the following tests. The dimension of our aptitude model (Gc, Gfv, Ff) measured by each test is indicated following the test name.

1. Vocabulary (Gc). A locally developed adaptation of several multiple choice vocabulary tests (to insure a wide range). Score is sum of performance on two, two minute sections.

2. Letter Series (Gfv). A local modification of the French et al. (1963) version. Score is sum of number correct on two, two minute sections.

3. Find a Shape Puzzle (FASP) (Gfv). A version of embedded figures where the simple and complex shapes are on the same page (Pulos & Linn, Note 11). Score is number of simple shapes located in four minutes.

4. Paper Folding (Gfv). From the French et al. (1963) battery. Score is sum of performance on two, two minute sections.

5. Water Level (Ff). A measure of perception of the horizontal adapted from Piaget by DeAvila et al. (1976). Score is number correct on eight trials.

Findings

The anticipated male-female differences in Predicting Displaced Volume and Proportional Reasoning emerged (Linn & Pulos, Note 7). At each grade, at least 5% of the variance in each task was attributable to sex. Males outperformed females at all ages.

Reliability

Both of the formal thought tasks were moderately reliable. Reliability of the Predicting Displaced Volume task was .82 in 7th grade and .86in 9th grade and Over 95% of the subjects could be assigned to one of the four strategies for Predicting Displaced Volume. The coefficient of scalability was .98 and of reproducability was .94. Thus, strategy usage was very consistent across items.

The Proportional Reasoning test was less reliable than the Predicting Displaced Volume test. Using alpha coefficients, 7th grade reliability was low (.31) but 9th grade (.61) and 11th grade (.64) had moderate reliabilities. The floor effect in 7th grade limited reliability. Considering items solvable with a weight-only strategy, for a test of similar length, the reliability would be .65 for seventh grade.

The aptitude measures were generally reliable with alpha coefficients ranging from .69 to .95 within each grade.

Male-female Differences in Strategy Usage

For each of the Formal Thought Tasks, females used inaccurate strategies more often but did not use different strategies than males.

For Predicting Displaced Volume, Linn & Pulos (Note 7) found that females used the weight-only strategy more than males and the volume only strategy less than males (Figures 3 & 4). The weight-except-when-equal and volume-except-when-equal strategies were used much like the weight-only and volume-only strategies but less frequently.

(Figures 3 & 4 about here)

Examination of solution strategies governing performance suggests that females lag behind males but follow the same progression. We found no evidence that females used unique strategies or, as a group, made slower progress with age than males. Female deficits in Predicting Displaced Volume reflected female use of weight-related strategies more than males. Males outperform females because volume-related strategies rather than weight-related strategies govern their performance.

For Proportional Reasoning, Linn & Pulos (Note 7) females used the correct strategy less often than males and instead used the weight strategy and the symmetry strategy (Figures 5 & 6). The distance strategy and the additive strategy are used infrequently but more by females than by males. Strategy usage was consistent for similar items but varied when items were Standard or Complex.

(Figures 5 & 6 about here)

Similar results for Proportional Reasoning are reported by Stage, Karplus, and Pulos (1980). They found that subjects used the same strategy for contextually similar items but used different strategies for items with contextual differences. They studied recipes for lemonade which indicated the amount of lemon and sugar used. Their items had either integral or non-integral ratios. In each item, the integral ratio could be for lemons, between recipes or for lemons and sugar within one recipe. They found that contextual factors like location of the integral ratio influenced strategy usage but that contextually similar problems were solved similarly.

Do students who use inaccurate strategies on Predicting Displaced Volume also use inaccurate strategies on Proportional Reasoning? The correlations between the two tasks are generally low (seventh grade r = .16; ninth grade = .28; eleventh grade r = .28). It appears that inaccurate strategy usage on one task is somewhat independent of inaccurate strategy usage on the other task.

Male-Female Differences in Aptitude and Experience Measures

Of the Aptitude and Experience measures, males out-performed females only on water level. On water level, males had a mean of 5.68, while females had a mean of 4.81. It should be noted that, contrary to many earlier studies reported by Maccoby and Jacklin (1974), we detected no male-female difference on FASP, our measure of Embedded Figures. Other recent studies (Petersen, Note 8); Fennema & Sherman, 1979) also find no male-female differences for measures similar to Embedded Figures. In addition we detected no male-female differences in number of courses taken although males took more advanced courses than females. Years of math and science was asked because courses in the three districts could not be easily equated.

Correlations Between Aptitudes and Formal Thought

The only significant male-female difference in correlations between the aptitude tests and formal thought was for seventh grade vocabulary score (males $r = .29$; females $= .03$; $z = 2.4$, $p < .01$). Vocabulary was more related to male performance than female performance. For seventh grade females, there was no relationship between vocabulary and formal thought. These results suggest that seventh grade females were less likely than males to use an overlearned or Crystallized strategy for formal thought tasks.

The relationship between Gc, Gfv, and Ff and each formal thought task is given in Tables 1 and 2 by grade. Gc, Gfv, and Ff each correlated significantly with formal thought (between .25 and .48) except that in seventh grade Gc correlated .16 with Predicting Displaced Volume, and .19 with Proportional Reasoning, reflecting the low seventh grade female correlations for vocabulary. The uniform correlations suggest an equal contribution of Gc, Gfv, and Ff to performance on Predicting Displaced Volume in ninth and eleventh grade.

(Tables 1 & 2 about here)

Correlations Between Course Taking Measures and Formal Thought

To determine whether course taking accounts for male-female differences in formal thought we correlated math and science course taking and formal thought. Interestingly, at ninth and eleventh grade (Tables 1 and 2), course taking was as highly correlated with formal thought as was Gc. Seventh grade correlations reflected the limited range in number of courses taken. Thus course taking experience correlated with formal thought performance.

Role of Aptitudes, Course Taking, Formal Reasoning, and School SES in Male-Female Differences in Formal Thought

The aptitude measures and the experience measures correlate with the measures of formal thought. Do they account for male-female differences in formal thought? The answer appears to be "No" as shown in Tables 1 and 2.

Partial correlations between sex and each formal thought test are used to determine whether male-female differences can be explained by the aptitudes and experience measures. The last column in Tables 1 and 2 gives the correlation between sex and the formal thought measure with aptitudes, other formal thought, and experience measures partialed out. As can be seen, these measures taken singly or together reduce the variance accounted for by sex in Predicting Displaced Volume from 6% to 5%. For Proportional Reasoning the variance accounted for by sex is not reduced at all by the aptitude, formal reasoning, and experience measures.

Does formal thought measure something besides Gc, Gfv, and Ff?

We entered formal thought in the regression equations in Tables 1 and 2 to determine whether there was any unique overlap between the formal thought measures. As can be seen, all of the explained variance in formal thought task performance is accounted for by Gc, Gfv, and Ff. Formal thought does not contribute any unique variance after Gc, Gfv, and Ff are entered.

Do Course Taking or School SES Measure a Unique Aspect of Formal Thought?

As can be seen in Tables 1 and 2, course taking and school SES do not account for any variance in formal thought not accounted for by Gc, Gfv, and Ff. For this population, course taking and school SES reflect aspects of Gc, Gfv, and Ff required for formal thought and do not measure unique aspects of formal thought.

Summary of Results of Studies of Predicting Displaced Volume and Proportional Reasoning

In summary the analysis of male-female differences in formal thought revealed:

1) Males out-perform females on Proportional Reasoning and Predicting Displaced Volume.

2) Both males and females consistently use accurate or inaccurate strategies on each of our formal thought tasks.

3) Although females use the inaccurate strategies more often than

males, they use the same inaccurate strategies in about the same proportions as the males do.

4) Aptitudes such as Gc, Gfv, Ff, Spatial ability, or formal reasoning, account for variance on formal thought task performance of all subjects, but do not account for male-female differences in performance.

5) Male-female differences in strategy usage on formal thought tasks are not explained by school SES or course taking. Both school SES and course taking correlate with performance on formal thought tasks but contribute no new variance after Gc, Gfv, and Ff are considered.

6) Use of an inaccurate strategy for one formal task does not imply that an inaccurate strategy will be used for another formal task. All of the overlap in formal thought task performance is accounted for by Gc, Gfv, and Ff.

Discussion

The studies summarized above reveal that males and females <u>consistently</u> apply accurate or inaccurate strategies to formal thought tasks but that aptitude measures are not sufficient to explain why males choose accurate strategies more frequently than females.

Results revealed that neither general ability nor aspects of spatial ability (Gfv, Ff) account for male-female differences in formal reasoning. Furthermore, male-female differences on one formal thought task do not account for differences on the other. Our indicators of experience (course taking and school SES) also do not explain why males choose accurate strategies more often than females. Clearly, aptitude explanations of male-female differences are not sufficient to explain our findings and our experience measures also did not explain our findings. Our discussion focuses on how experience in math- and science-related activities might contribute to male-female differences in formal thought even when both sexes take the same number of courses.

Shortcomings of Our Experience Measures

We hypothesized that male-female differences in formal thought would reflect differential experiences. Our two measures of math and science experience, course taking and school SES correlate with formal thought but do not explain male-female differences in performance.

Early studies (e.g., Fennema & Sherman, 1977,1979) demonstrated that male-female differences in math achievement disappeared when course taking was equalized. At that time, however, females were under-represented in advanced math courses, so correcting for course taking may have resulted in comparing females high in general ability to males who were less talented. Recently, Armstrong (1979) drew a national sample of 11th graders and found that participation in advanced math classes is now evenly distributed between males and females but that females' inferior performance was no longer explained by course taking. We found, like Armstrong, that course taking did not explain male-female differences in reasoning. We also found that course taking correlated with general ability, supporting our interpretation of Fennema.

One hypothesis about course taking is that recent efforts to encourage females to continue in math and science may result in poorly prepared females taking math courses. These females may perform less well than males because they lack the prerequisite experiences. This could occur either because they did not take appropriate courses or because they were treated differently in the courses they took. Thus course taking may be a poor measure of experience.

On the formal thought tasks, neither course taking nor school SES account for unique variance after Gc, Gfv, and Ff are considered, suggesting that, for this population, our experience measures overlap substantially with general ability.

Affective and Social Factors

The Proportional Reasoning test used by Linn & Pulos (Note 7) in this study was also used by Petersen (Note 8) in a longitudinal study. Petersen's study augments our findings by examining the influence of Affective and Social factors on reasoning. The affective and social factors which she measured accounted for very little of the variance in Proportional Reasoning after general abilities were entered. No consistent pattern of social or affective influence emerged.

Other Influences of Experience

How else could experience contribute to males' and females' formal thought performance? The effects of experience might be more specific than our methods of detection can reveal. Several findings support the specific influences of experience: 1) Most subjects use a single strategy to solve each formal thought task--specific strategies have been learned; 2) Development of an inaccurate strategy for one formal thought task does not predict whether another formal thought task will be solved using an inaccurate strategy; 3) Females use inaccurate strategies more often but do not use different strategies than males--females may have fewer experiences than males that encourage them to change their strategies once they have acquired their first strategy.

Do females have different experiences than males in math and science? We examine 1) free choice environments, 2) style of problem solving, and 3) response to contradiction as opportunities for differential male and female experience.

Free Choice. Research on free choice environments reveals that females choose different experiences than males (Linn, 1980a; Linn & Thier, 1975; Rice & Linn, 1978). For example, Rice and Linn (1978) studied 60 junior-high students participating in a hands-on science program where they could choose from among 40 different acticities. Females, more than males, chose activities which required neatness, following recipes for chemicals, or following clearly defined rules. Males more often than females chose activities which allowed exploration of mechanical apparatus, computation, development of skill, and open-ended responses. These results suggest that males more than females would choose an activity involving displacement of volume since it would be open-ended and involve apparatus. Perhaps females avoid apparatus to update their knowledge of Predicting Displaced Volume. Many writers have suggested that females avoid mathematics (e.g., Tobias, 1978; Fox 1977), and therefore avoid opportunities to update their knowledge of Proportional Reasoning. Thus, females may have more inaccurate strategies because they avoid opportunities to revise their strategies.

Style of Problem Solving. Do females approach problem solving in math and science differently? Attitude toward problem solving is an important dimension. Resek's (Note 12) evaluation of students in remedial college math classes revealed those who could be described as strategy followers and those who could be described as strategy finders. Strategy followers learn rules and apply them as best they can, but do not figure out why the rules work. Strategy finders focus on understanding the rules they are taught. Strategy followers tend to fail when confronted with a special case while strategy finders alter their rules, according to the situation. On math computation items, these two groups are often indistinguishable, but on algebra word problems, strategy followers often fail.

It appears that females are more likely to be strategy followers than strategy finders (Resek, Note 12). Strategy followers have great difficulty when their rules don't work, but may do as well as or better than other students on the problems the rules were designed for. Strategy followers may be less likely to detect and act on the information that their strategies are inaccurate. Strategy followers, being uncertain about how to get a new strategy, may avoid information which could contradict their strategy. In contrast, those who are strategy finders are likely to do thought experiments to verify their strategies.

Thus females and males may initially expect weight to be important in the amount of liquid displaced by a metal cube because weight is an important variable in other problems like determining how much a spring will expand when a weight is attached, or how much a toe will hurt when hit by a weight. To overcome this expectation the learner must recognize a contradiction between the weight-only strategy and physical reality. The learner could do an apparatus-based experiment, with different sized ice cubes for example, or a "thought" experiment. A thought experiment involves checking to see if the weight strategy is consistent with other strategies. Subjects who can conserve liquid, who can maintain volume constancy and who can combine quantities will realize that the weight strategy violates their idea of volume constancy. Thus, strategy finders, by seeking consistent strategies might eliminate their inaccurate weight-only strategy, while strategy followers might never check strategy consistency.

What happens when the strategy doesn't work? Do students get anxious? We hypothesize that the answer is "not always." Students who have previously been successful in math and who are strategy followers are likely to be anxious when their strategies don't work. Students who don't think math is important are unlikely to be anxious. Students who haven't done well previously probably don't get anxious when their strategies do not work, since their strategies rarely work. Students who are strategy finders are also unlikely to be anxious, since they can find a new strategy. Thus we hypothesize that the commonly discussed math anxiety may contribute to differential experiences of males and females but that anxiety has a complex effect on performance. To eliminate a strategy students must recognize a contradiction and find a better strategy.

Response to Contradiction. During science instruction, learners often get evidence contradicting their strategies. How do they respond? Is a contradiction of their strategy a challenge to figure out what went wrong and devise a better strategy? Do learners ignore contradictions? Does a contradiction of their strategy discourage them from further exploration of the task or further exploration of science? Does a contradiction suggest that they are stupid and unable to learn science? How individuals respond to contradictions influences how they acquire science literacy.

Do females and males respond differently to precise feedback which indicates they have inaccurate ideas? One study suggested that females often ignore precise feedback and continue to "get confused," or "refuse to reason" (e.g., Linn, 1980b) or blame the teacher when they are confronted with contradictory evidence. It remains to be seen whether males are more likely than females to seek new explanations and revise their ideas when confronted with evidence that they are wrong.

Females may avoid science activities more often than do males possibly because they wish to avoid being wrong. We know that females avoid being wrong more often than males by leaving multiple-choice items blank rather than guessing (Harris & Wheeler, Note 13), and by checking "I don't know," rather than an answer for National Assessment of Educational Progress science items (NAEP analysis, Note 14). Thus, females avoid being wrong, and avoid being right, too. If females avoid being wrong in learning situations they will not find out that their strategies are inaccurate but, of course, they won't know if their strategies are accurate either. Thus, females may be reducing the effectiveness of their math and science learning experiences by avoiding activities with specific feedback.

Understanding of response to science learning opportunities will suggest why exposure to science tasks is often uneven. Students may know a lot about proportions but very little about pulleys. We found that students use inaccurate solutions consistently for similar problems but that the same students do not use inaccurate solutions on unrelated problems. Thus, acquisition of inaccurate solutions for science-related concepts may reflect the individual's experience with the concepts. Males and females may respond differently to opportunities to verify their strategies. Strategy finders are more likely to verify their strategies than strategy followers and are more likely to be males. Males are also more likely to seek contradictions to their strategies than females. Differential male-female response to contradictions may account for differential acquisition of science strategies.

Peer, teacher, and family responses to male and female efforts to solve math or science problems may contribute to females avoidance of contradiction. For example, if male failures of math problems are greeted with responses like "Everyone hits a few bumps on the way to the top," but female failures are greeted with responses like "Oh, I guess she isn't as smart as I thought she was," there would be a strong incentive for females to avoid failure by refusing to guess.

Conclusions

We investigated male-female differences in formal thought task performance. Studies reveal that aptitudes such as spatial visualization, commonly hypothesized (e.g., Harris, 1978) to account for male-female differences in formal thought does not reduce the variance attributable to sex. Since subjects consistently follow inaccurate strategies for some formal thought tasks but not others, choice of science and math activities and exposure to specific contradictory evidence may play a role in male-female differences. In addition, females may respond differently than males to information which contradicts their strategies. Finally females may perseverate in avoiding contradiction because their errors are taken more seriously by peers and teachers than errors by males. Since our findings suggest that experience plays an important role in reasoning performance, these potential explanations deserve further study. To insure that both male and female opinions influence science policy the scientific literacy of both must be encouraged.

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Table 1

Multiple Regression (Fixed Order) for Proportional Reasoning by Grade

	Correlation	Multiple Regression			Partial Correlation[1]
	r	R	R^2	F to enter	
Seventh Grade					
Gc	.19	.19	.04	9.03 **	.13
Gfv	.31	.32	.10	17.87 ***	.14
Ff	.24	.34	.11	3.19 ns	.11
Formal	.17	.34	.11	.32 ns	.11
School-SES	.04	.34	.12	1.11 ns	.11
Course	.04	.35	.12	.65 ns	.11
Sex	.14	.36	.13	2.89 ns	.11
Ninth Grade					
Gc	.27	.27	.07	11.75 ***	.24
Gfv	.45	.46	.21	28.15 ***	.33
Ff	.35	.49	.24	4.62 *	.31
Formal	.22	.50	.25	1.53 ns	.29
School-SES	.16	.50	.25	.01 ns	.29
Course	.25	.50	.25	1.32 ns	.31
Sex	.26	.57	.32	15.46 ***	
Eleventh Grade					
Gc	.31	.31	.09	20.43 ***	.34
Gfv	.48	.50	.25	39.81 ***	.33
Ff	.29	.50	.25	1.54 ns	.32
Formal	.23	.52	.27	5.36 **	.31
School-SES	.24	.52	.28	.94 ns	.31
Course	.29	.53	.28	.88 ns	.31
Sex	.29	.59	.35	20.58 ***	

ns = not significant

* $p < .05$
** $p < .01$
*** $p < .001$

[1] Correlation between sex and volume with all variables entered in regression to this point partialled out.

Table 2

Multiple Regression (Fixed Order) for Predicting Displaced Volume by Grade

Seventh Grade

	Correlation	Multiple Regression			Partial Correlation[1]
	r	R	R^2	F to enter	
Gc	.16	.16	.03	6.74 **	.24
Gfv	.25	.26	.07	11.14 ***	.22
Ff	.27	.31	.10	71.92 **	.25
Formal	.17	.32	.10	.49 ns	.22
School-SES	.21	.34	.12	4.50 *	.22
Courses	.12	.36	.13	3.13 ns	.21
Sex	.24	.41	.17	11.10 ***	

Ninth Grade

	r	R	R^2	F to enter	Partial Correlation[1]
Gc	.32	.32	.10	17.59 ***	.27
Gfv	.29	.37	.14	6.45 **	.25
Ff	.36	.44	.19	10.36 **	.27
Formal	.22	.44	.19	.08 ns	.27
School-SES	.21	.45	.20	1.24 ns	.27
Courses	.24	.46	.21	1.76 ns	.27
Sex	.29	.52	.27	11.50 ***	.27

Eleventh Grade

	r	R	R^2	F to enter	Partial Correlation[1]
Gc	.22	.22	.05	10.50 **	.35
Gfv	.33	.34	.12	15.24 ***	.30
Ff	.35	.41	.17	12.23 ***	.34
Formal	.23	.41	.17	.04 ns	.30
School-SES	.15	.41	.17	.54 ns	.30
Courses	.26	.42	.18	.80 ns	.30
Sex	.32	.50	.25	18.57 ***	.30

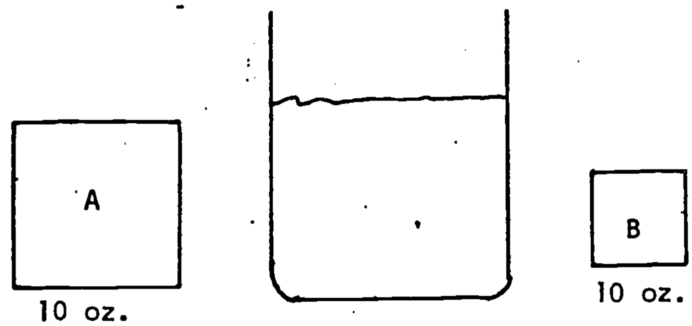
ns = not significant

* $p < .05$
** $p < .01$
*** $p < .001$

[1] Correlation between sex and volume with all variables entered in regression to this point partialled out.

Figure 1

Block A is larger than Block B. Both blocks weigh the same.

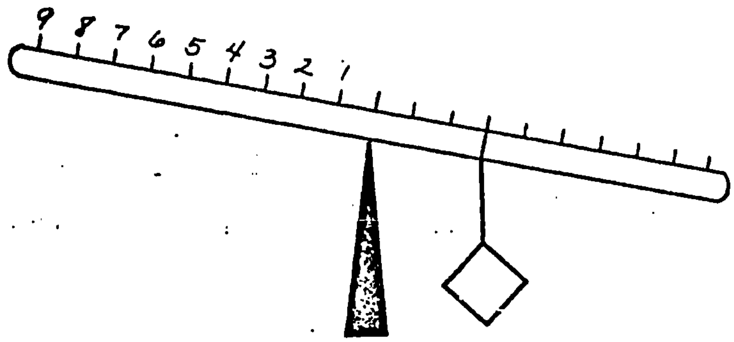


Which block will make the water go up higher?

Block A

Block B

Both the same



Where should a 2 gm. weight be placed to make the beam balance?

a) 1

b) 4

c) 3

d) 9

Figure 3

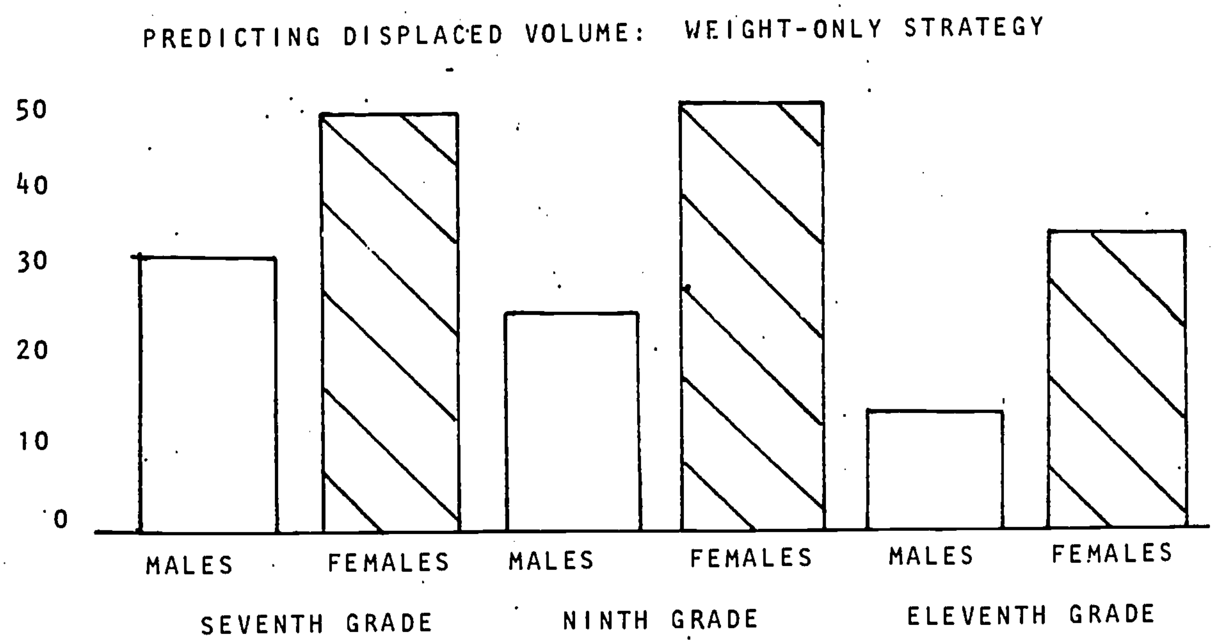

PREDICTING DISPLACED VOLUME: WEIGHT-ONLY STRATEGY
50
40
30
20
10
0
MALES
FEMALES
MALES
FEMALES
MALES
FEMALES
SEVENTH GRADE
NINTH GRADE
ELEVENTH GRADE

Figure 4

PREDICTING DISPLACED VOLUME: VOLUME-ONLY STRATEGY

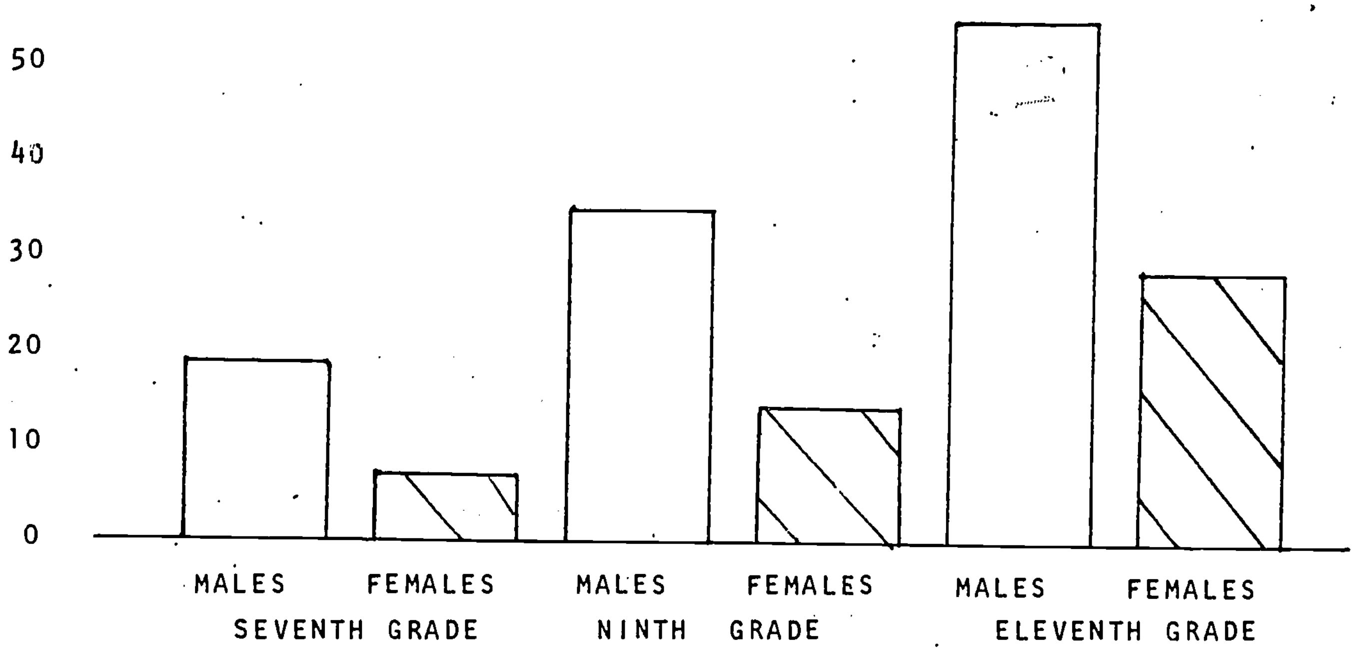
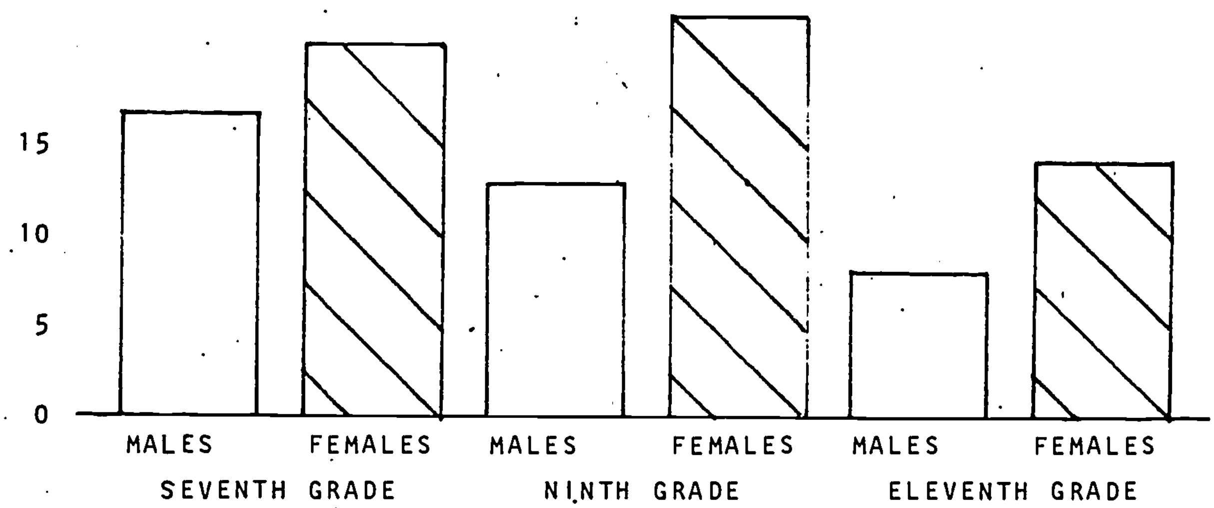


Figure 5

PROPORTIONAL REASONING: PERCENT USING THE SYMMETRY STRATEGY



PROPORTIONAL REASONING: PERCENT USING WEIGHT STRATEGY

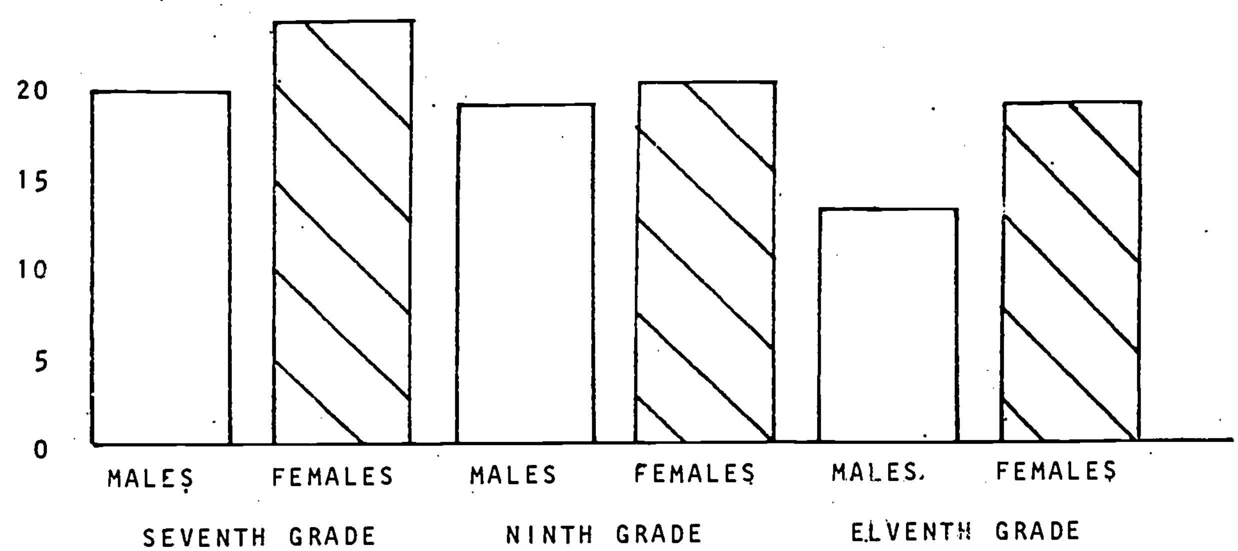
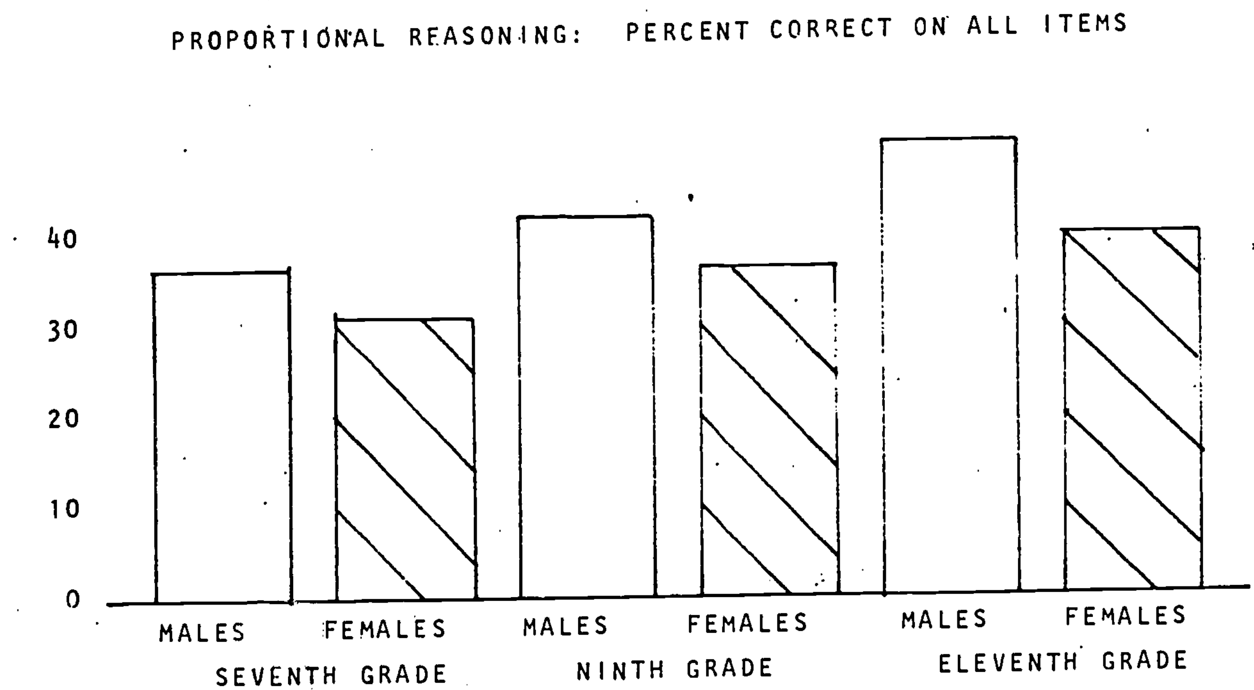


Figure 6


PROPORTIONAL REASONING: PERCENT CORRECT ON ALL ITEMS
40
30
20
10
0
MALES
FEMALES
SEVENTH GRADE
MALES
FEMALES
NINTH GRADE
MALES
FEMALES
ELEVENTH GRADE