GENDER-RELATED DIFFERENCES IN MATHEMATICS ACHIEVEMENT

An Honors Thesis (HONRS 499)

by

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INTRODUCTION

For many years there has been an ongoing controversy regarding whether or not males are superior to females in mathematics achievement. Although sex differences have been noted in verbal skills, spatial visualization, computational skills, problem solving abilities, anxiety, attitude toward success in mathematics, courses taken in mathematics, and the stereotyping of mathematics as a male domain, there are still discrepancies between findings of various experimental studies. It has been suggested that the variables noted may have a strong influence on mathematics achievement and ability. However, there may have been inconsistencies, design weaknesses, and other variables not considered in many of these studies that warrant a need for additional research. The purpose of this paper is to compare the results of many studies in the current literature that are designed to determine if gender-related differences in mathematics achievement can be explained by these and other variables.

REVIEW OF LITERATURE

Research by Hilton and Berglund (1974) was designed for the purpose of studying sex differences in mathematics achievement and how these differences change with age. Data was utilized from the Growth Study which was begun in 1961 at Educational Testing Service. The study attempted to keep the amount of mathematics training constant while dichotomizing the subjects into academic and nonacademic categories. It should also be noted that investigators believed that this test was relatively free from sex bias, could be used in schools with somewhat different mathematics programs, and was composed of appropriate content which measured the mathematics being taught in the schools. In 1961, a nation-wide sample of fifth-grade students was taken. Then, every two years thereafter, samples were selected from seventh, ninth, and eleventh-grade students. Each year the test form remained very similar to the original form with increases in difficulty of the reading level of the items on each test. The investigators expected to find little difference in mathematical achievement between the sexes in the preadolescent years (near fifth-grade), and then observe that differences in achievement would widen as students moved forward through their education.

Results showed that at grade five there was no difference, but at grades seven, nine, and eleven, males had a higher mean score. Despite these results, investigators were unable to conclude that males are superior in mathematics achievement as a result of uncontrolled variables. Some of the uncontrolled variables noted in this study were the subjects' levels of interest in mathematics, preconceived notions toward one's abilities in mathematics, and teacher influence on student achievement.

In a study by Fennema and Sherman (1977), mathematics achievement, general ability, verbal ability, and spatial visualization were the cognitive variables considered. Affective variables considered were stereotyping mathematics as a male domain, perceived attitudes of mother, father, and teacher toward the student as a learner of mathematics, and usefulness of mathematics. Other variables studied were number of mathematics related courses taken, number of space related courses taken, and amount of time spent outside of school in mathematics related activities.

In the study, 589 females and 644 males participated. Students were predominantly white, in grades nine through twelve, and enrolled in mathematics courses from four schools. For this study, students enrolled in general mathematics classes were not used. Students were tested in their own classrooms by trained administrators (both male and female) over four classroom periods. Many of the variables considered in this study were addressed with separate tests. Other variables were addressed through surveys completed by the student.

The overall results of this study showed no significant differences in mathematical ability between the sexes. Males did, however, tend to have higher mean scores as grade level increased.

In a follow-up study, Fennema and Sherman (1978) considered students in grades six through eight. Students used for this study were from feeder schools to the four high schools used in the previous study. The main objective of the study was to obtain measures of mathematics learning. This test included items that required computational skills, knowledge of concepts, and problem solving ability. The items on this test were formulated so that approximately half involved male-appropriate content and half involved female-appropriate content. The ratio of male names to female names used in items on this test was approximately 1:1. Again, the cognitive variables measured were mathematics achievement and spatial visualization.

This study also included about thirteen hundred students and general mathematics students were again eliminated from the study. Results indicated no significant sex related differences at the sixth through eighth-grade levels.

Benbow and Stanley (1980) considered data from six separate talent searches in 1972, 1973, 1974, 1976, 1978, and 1979. These searches were completed by the Study of Mathematically Precocious Youth (SMPY) and included 9,927 gifted junior high and high school students (grades seven through ten). For the searches in '72, '73, and '74, seventh, eighth, and accelerated ninth and tenth graders were tested. For the searches in '76, '78, and '79, only students in seventh-grade participated. The sample tested was 43% female and 57% male.

As part of the talent search, students took both parts of the Scholastic Aptitude Test (SAT). The SAT consists of a mathematics test and a verbal test. The mathematics portion of the SAT was used to test the hypothesis that very little or no differences between boys and girls in mathematical aptitude exist.

Findings of this study included a notable difference in mathematical ability in favor of males. It was also found that females outperformed males on the verbal portion of the test.

Armstrong (1981) reported on the results of two national surveys so as to provide information on participation in mathematics and mathematics achievement for males and females. The first source of data was the Women in Mathematics Project (1978), conducted by the Educational Commission on the States (ECS). Information collected dealt with achievement and participation in mathematics. It also dealt with factors such as attitude, social influence, and educational variables related to participation and achievement in mathematics. Subjects included thirteen year olds and high school seniors.

The second data source was provided by the National Assessment of Educational Progress (NAEP). This assessment included test items that were administered to students aged nine, thirteen, and seventeen.

Results of the first data source indicated differences in achievement favoring males in the sample of high school seniors. With the sample of thirteen year olds, females were superior to males on the computation and spatial visualization items. Results of the second data source showed that males outperformed females only on the problem-solving items. There were no significant sex differences relative to spatial visualization.

A study by de Wolf (1981) was designed to determine if mathematics achievement of males would be superior to that of females if the amount of mathematics coursework was controlled.

There were six tests used in the study, all of which were from the Washington Pre-College Testing Program (WPC). These tests included the Quantitative Skills, A, Quantitative Skills, B, Applied Mathematics, Mathematics Achievement, Spatial Ability, and Mechanical Reasoning. Quantitative Skills, A, was designed to measure the ability to determine whether enough information was given to solve a problem. Quantitative Skills, B, was designed to measure the ability to determine relative size of two given quantities. The Applied Mathematics test was designed for applying knowledge of arithmetic and elementary algebra to solve practical problems. The Mathematics Achievement test involved testing students' knowledge of algebra and geometry. The Spatial Ability portion tested students' ability to visualize transformations in three dimensions. Finally, The Mechanical Reasoning test was designed to assess students' ability to understand physical principles as applied to mechanical devices.

In this study subjects consisted of 962 males and 1131 females. All of these individuals were juniors in high school. In addition, these tests were administered to all subjects in the second semester of their junior year. Students' high school transcripts recorded semester credits for grades nine through eleven and grades assigned for previous mathematics and physics coursework.

The results of this study suggested that sex differences in quantitative abilities and spatial ability are partially a reflection of differential mathematics training.

Stones, Beckmann, and Stephens (1982) investigated gender differences in the achievement of mathematical competencies among college students in precalculus courses.

The test used in this study, the Beckmann-Beal Mathematical Competencies Test for Enlightened Citizens, was designed to measure achievement on the identified mathematical competencies. The test, which had a total of forty-eight items, was divided into the following categories and numbers of items: Numbers and Numerals-7, Operations and Properties-8, Mathematical Sentences-3, Geometry-5, measurement-5, Relations and Functions-3, Probability and Statistics-4, Graphing-4, Mathematical Reasoning-3, and Business and Consumer Mathematics-6.

The sample consisted of 570 males and 476 females who were enrolled in classes that could be categorized as college algebra, mathematics for elementary teachers, or applied mathematics. Students chosen were attending one of ten institutions including four state colleges and six community colleges.

Results of the data analysis showed that males excelled in areas where specific knowledge of course content was important. It also showed that females excelled in areas where the ability to reason mathematically was important. However, it was reported that no significant differences could be found that would relate mathematics ability to gender.

Fulkerson, Furr, and Brown (1983) investigated achievement and expectations among third, sixth, and ninth-grade black and white males and females. The authors of this study tested hypotheses that boys in each grade will have greater expectations of achievement than girls of the same grade, but only ninth-grade boys will have higher achievement; ninth-grade students will display higher achievement as compared to sixth-grade students who will display higher achievement as compared to third-grade students; white students will have greater expectations and higher achievement than black students; and there will be no significant sex-related or race-related differences in realism of expectations.

Forty ninth-grade students, 36 sixth-grade students, and 36 third-grade students were randomly selected from the same school. The sample included 26 black males, 26 black females, 29 white males, and 31 white females.

A single investigator tested all students in small groups. Each group was shown samples in each of the tasks of mathematics, geometric drawings, and mazes. Each of these tasks had eight levels of difficulty. The groups were first shown an example of the simplest level and then an example of the most difficult level of each of the three tasks. They were then asked to estimate the number of each of the eight levels they could complete in a given period of time. After recording their expectations, the subjects completed each of the three tasks.

Results of this study did not support all of the original hypotheses. Boys did not have greater expectations of achievement than did girls. Third and sixth-grade boys and girls scored equally in mathematics achievement as expected; however, ninth-grade boys did not outscore ninth-grade girls. In addition, ninth-grade students did achieve higher than sixth-grade students who did achieve higher than third grade students. Finally, it could not be shown that white students had higher expectations of achievement than black students. Overall, there were no significant sex-related or race-related differences in realism of expectations.

A study by Senk and Usiskin was designed to determine if sex differences in mathematical ability in geometry proof writing exist. Data analyzed were from the Cognitive Development and Achievement in Secondary School Geometry (CDASSG) project. The CDASSG sample includes 2699 students from 99 geometry classes in 13 public schools across five states. In the first month of the school year, a test was administered to measure students' prior knowledge of geometry. In the last month of the school year, investigators administered a test called the Comprehensive Assessment Program (CAP), a standardized geometry achievement test. Students also took a CDASSG test which consisted of geometry proofs only. The proof tests consisted of six different proofs in which students had to fill in missing steps on two proofs and write complete proofs on four items. All tests were given by classroom teachers.

Eight experienced high school teachers graded the proof tests. Proof items were graded using a scale of zero to four. Performance on proof-writing was measured and calculated in two ways. First, "total score" was the sum of correct items on the fill-in portion of the test and the second, called "the number of proofs correct," was the number of proof items upon which the student received a three or four.

The results of this study indicated that although females entered geometry class with slightly less knowledge of geometry than males, they left their geometry class with as much knowledge as did males.

A study by Wolleat, Becker, Pedro, and Fennema (1980) dealt with the confidence and anxiety differences between males and females regarding mathematics. Six hundred forty-seven females and 577 males enrolled in college preparatory mathematics classes in ten high schools in the Midwest served as subjects. Students' perceptions of the causes of their own performance were measured by the Mathematics Attribution Scale.

Results showed significant sex differences in favor of males in perception of success related to ability and in perception of success related to effort. In addition, females tended to believe their failure was related to lack of ability or that the task was too difficult. However, as achievement scores of females increased, so did their belief that effort was related to success. On the other hand, as achievement scores of males increased, the belief that effort was related to success decreased.

Leder (1980) conducted a survey that showed the performance of males in mathematics exceeds the performance of females. Scores were taken from the Victorian Higher School Certificate (HSC) 1970-1979. The scores showed no significant differences in performance when comparing those receiving "passing" grades (C or better). However, there were significant differences in performance when comparing those receiving an A grade. Males consistently achieved a higher level than did females. It was also proposed by Leder that fear of success was relevant to sex differences found in mathematics achievement.

Becker (1981) completed a study designed to determine if teacher influence is related to differences in achievement between males and females in mathematics. Student responses to the teacher in three high schools in two school systems were observed and recorded. Seven female and three male secondary geometry teachers were observed a total of ten times each. Becker performed all 100 observations. As a control measure, a second observer was present for eleven observations to ensure the reliability of Becker's observations. Scott's coefficient was used to assess reliability of the observer in the use of the Brophy-Good Teacher-Child Dyadic Interaction System as an instrument of analysis.

The sample was from an urban/suburban and rural school and consisted of 50% males and 50% females. The Brophy-Good Teacher-Child Dyadic Interaction System was used as a rating scale for sex differences. In addition, interviews with students, teachers, administrators, and guidance counselors were used to provide further information.

Analysis of data from three out of six observational tests showed significant differences in behavior favoring males. No significant differences in the quality of answers between males and females were found; however, males were more likely to receive feedback that maintained student/teacher interactions. In addition, teachers were more likely to interact informally with males than with females. Despite these observations, females tended to initiate student/teacher interactions more often than males. In using praise and criticism, teachers were most often directing their comments toward male students. Becker also found that females having the same ability as males received better grades but did not receive extra attention. Finally, teacher language and behavior was also supportive of the traditional view of mathematics as a masculine domain.

Parish and Wheatley (1973) performed an experiment on 26 male and 25 female students at the second grade level. The purpose of this experiment was to determine if the sex of the teacher (experimenter) resulted in significant differences in the performances of the students.

Students were randomly grouped into one of two test groups. A single experimenter, one male and one female, was assigned to each test group by flipping a coin. The instrument used for testing was an octagonal board with a pair of movable parallel rods. There was a practice session given before each test of length conservation which involved books of equal and unequal size. A series of nine questions were asked including a response breaker. Items 1 and 2 were practice items, items 3 and 4 were labeled "Length Pretest," items 5 and 6 were labeled "Length Conservation," item 7 was the response breaker, and items 8 and 9 were also "Length Conservation" items.

In the group led by the male experimenter, 4 males and 3 females were conservers, and 10 males and 8 females were nonconservers. In the group led by the female experimenter, 6 males and 9 females were conservers, and 6 males and 5 females were nonconservers. Thus, the total number of conservers to nonconservers for the male experimenter was 7 to 18 respectively, and the total number of conservers to nonconservers for the female experimenter was 15 to 11 respectively. These results showed the total number of conservers under the female experimenter to be greater than the total number of conservers under the male experimenter. Thus, sex of the experimenter did appear to be an important factor involved with operational conservation of length for students at the elementary level. In addition, it was also noted that male and female children did not appear to respond differently to a given test administrator.

Duval (1980) studied the relationships between gender and/or ability and the grade assigned on a mathematics task. To achieve an appropriate sample, Duval first divided New York into ten homogeneous regions by county. From each of these regions, 102 teachers were randomly selected and assigned to an experimental group. There were seven experimental groups in all. Each teacher received a packet containing the following:

A cover letter with false explanation of the purpose of the exercise, guidelines for correcting examinations, an examination paper and profile of each student, a stamped postcard enabling teachers to receive results of the study, and a teacher questionnaire. With the passing of several weeks and after follow-up mailing, only 315 responses were returned out of the total 1,020 original packets sent.

Results showed that female students of average ability achieved the highest mean score. This suggests that this group was evaluated with different standards than the groups of females of high or low ability. In addition, low ability males were graded with a more lenient scale than the low ability females. Overall, the original hypothesis that the gender or ability level of each student would affect the grade given on a mathematics task was not supported by the data.

A study by Fennema and Tartre (1985) provided additional information about the relationships among mathematical problem-solving performance, spatial visualization, verbal skills, and gender-related differences in mathematics performance. Another objective of this study was to determine how spatial visualization and verbal skills are used in problem-solving and if this usage is different for the two sexes.

The sample was selected from a population of 669 sixth-grade students. The tests that were administered were designed to measure spatial visualization, verbal skills, and mathematics achievement. The sample population actually consisted of students who scored in the upper third on the spatial visualization test and in the lower third on the verbal test (high sv/low v), or in the lower third on the spatial visualization test and in the upper third on the verbal test (low sv/high v). In the high sv/low v category, there were 17 males and 18 females. In the low sv/high v category, there were 16 males and 18 females.

The Space Relations portion of the Differential Aptitude Test was used to obtain measures of student spatial visualization. Verbal skills were measured by the Cognitive Abilities Test, Verbal Battery. In addition, the Mathematics Basic Concepts subtest of the Sequential Test of Educational Progress was used to measure eighth-grade mathematics achievement.

The Instrument to Measure Mathematical Thinking (IMMT) was composed of word problems and problems dealing with fractions. In addition, each problem was composed of three phases: Verbalization, solution, and explanation. In the verbalization phase, students were asked to silently read the given problem and then restate it in his/her own words. In the solution phase, students were first asked to draw a picture that would help them solve the problem. They were then asked to actually solve the problem using the picture. In the explanation phase, the student was asked to explain how he/she had used the picture to solve the given problem.

The results of this study showed that students with high spatial visualization skills did not solve more problems than students with low spatial visualization skills. It was also reported that males were able to solve significantly more problems emphasizing the use of spatial visualization skills than females.

Liben and Golbeck (1980) conducted a study using a sample of students in the third, fifth, seventh, ninth, and eleventh grades from a school in Pennsylvania. The original sample included 331 students but was reduced to 240 for the final study. An equal number of male and female students were used.

The tests given to the students dealt specifically with the concepts horizontality and verticality. Nonphysical horizontality test booklets used pictures of identical rectangles randomly placed at angles of 30°, 50°, 70°, 110°, 130°, and 150°. Students were instructed to draw horizontal lines across each rectangle. The physical horizontality test utilized a picture of a water glass and asked students to record the level of the water at various angles. The nonphysical verticality test was analogous to the nonphysical horizontality test. In this test, students were instructed to draw "straight up and down lines" from a dot given on a side of each of the rectangles. Again, each of the rectangles was randomly placed at one of the angles used in the horizontality test. The physical verticality test utilized a picture of a van with a light bulb suspended from a cord attached to the ceiling of the van. Vans were shown one at a time at an incline of 15°, 30°, 50°, 130°, 150°, and 165° in random order. Students were asked to record the position of the light bulb on the cord in relation to its respective van.

The results of the tasks involving horizontality showed no differences between males and females; however, the students did tend to improve their scores with each increase in grade. The same results occurred with the vertical tasks. It was also reported that performance on nonphysical tasks was significantly better than performance on physical tasks.

Moore and Smith (1987) compared mathematical aptitude of young people with varied background and schooling. The data used came from the National Longitudinal Study of Youth Labor Force (NLS) between the years of 1979 and 1981.

In this study, 5969 males and 5945 females comprised the sample. The NLS divided this sample into three different samples. These included a full probability sample of noninstitutionalized civilian segment of American population, aged 14 through 21, a supplemental oversample of civilian black Hispanic, and economically disadvantaged white youth, aged 14 through 21, and a probability sample of youth serving in the military, aged 17 through 21. All three of these samples were combined for analysis.

The instruments used were taken from the Armed Services Vocational Aptitude Battery (ASVAB), Form 8A. Included was an arithmetic reasoning test and a test of mathematical knowledge. The arithmetic reasoning test assessed ability to solve word problems, while the mathematical knowledge test was designed to measure the respondents' knowledge of principles of mathematics normally taught in algebra, geometry, and trigonometry courses.

Males generally outperformed females on both parts of the test. Results also showed that differential course taking in high school appeared to be a significant factor in performance.

Ethington and Wolfle (1984) conducted a study that re-examined the reasons men and women differ in mathematics achievement. This was done using data from the "High School and Beyond" study (HSB), a longitudinal study of high school sophomores and seniors which was sponsored by the National Center for Education Statistics.

Spatial visualization, mother's education, and father's education were each used as a single variable in this test. In addition, mother's education and father's education were assumed to be measured with perfect reliability. Two ability variables were measured. The first, spatial visualization, was measured by a test entitled "Visualization in Three Dimensions Test." The second ability variable involved grades, attitudes about mathematics, and individual exposure to mathematics. The grade factor included a report of a student's high school grades as well as a report of his/her grades in mathematics courses. The attitude factor was measured by using student perception of usefulness, interest, and importance of mathematics. Exposure to mathematics was measured by five variables indicating enrollment in high school courses. These courses include Algebra 1, Algebra 2, Geometry, Trigonometry, and Calculus. In addition, mathematics achievement was measured by scores from two parts of the HSB mathematics test. Subject participation included 7115 females and 6085 males.

Men were found to score higher than women on a combined test of mathematics, even after the effects of parental education, spatial and perceptual abilities, high school grades, attitudes toward mathematics, and mathematics exposure had been controlled. These differences were not significant.

Monaco and Gentile (1987) completed a study designed to test whether learned helplessness treatment would decrease performance on mathematical tasks. It was also designed to extend the learned helplessness findings to include the cognitive development dimension.

The subjects for this study consisted of 128 high school students in grades nine through twelve. Half of those participating were male, and half were female. All levels of mathematical ability were represented.

There were three parts of a seminar given and a different instructor conducted each part. The three parts were a developmental pretest, a strategy training session, and helplessness training session. The Understanding in Science Test was administered to all subjects in tenth through twelfth-grade to classify them according to cognitive operational level. The next day, half of the formal operational males and females and half of the concrete operational males and females were given higher strategy training. The remaining half of each group of students received no further training.

A pattern completions test was then given to each subject. The subjects with no extra training were given simple instructions and were not allowed to ask questions. The subjects with extra training were allowed to ask questions and received hints. On the third day, helplessness treatment was given to the same group of students that had received training earlier in the study. This group then completed a multiplication test. Then, the "failure group" was told that they had failed to complete the same number of problems as their classmates. This step was completed a total of five times.

Next, all subjects were required to complete a task on multiplication that was very similar in format to the multiplication tests that were repeated five times. Then, all subjects completed a parallel form of the pattern completion test given earlier in the training/no training sessions. It was responses to these two tests from which results were drawn. All participants were given an opinion survey to examine differences in ideals about oneself and one's abilities.

Overall, students labeled as formal operational scored higher on both tests. Students receiving training performed better on the test of pattern completion than students who received no training. Experimenters also found that females did not perform as well as males on either test. Finally, the expected three-way interaction between gender, developmental operational level, and helplessness treatment could not be supported.

RESULTS

Hilton and Berglund (1974) investigated the possibility of differences in interests as causes of differences in mathematics achievement. Grades five, seven, nine, and eleven were studied, and achievement scores tended to increase with each successive grade level. The Sequential Test of Educational Progress (STEP), the School College Ability Test (SCAT), and a 177 item Background and Experience Questionnaire (BEQ) were the instruments used. The different forms of the STEP and the SCAT were vertically equated for each grade level. The BEQ used essentially the same form each time with increases in reading difficulty of the items. The STEP series measured students' ability to apply problem solving skills in reading, writing, listening, social studies, science, and mathematics. The SCAT series yielded verbal (V) and quantitative (Q) scores in order to measure general ability to do school work. This study utilized STEP Mathematics and SCAT-Q portions of the tests. The BEQ was designed to relate academic growth to student experiences and activities in and out of school.

The analysis of data utilized t-tests with α-levels .05, .01, and .001. Students chosen for the study all had similar backgrounds in mathematics. This may have reduced the true randomness of the sample.

Results showed that there were no significant differences at grade five; however, sex differences did tend to increase with age. In both ninth and eleventh grades, males scored significantly higher than females ($\alpha = .001$). For the seventh-grade group, males scored significantly higher than females ($\alpha = .05$). Investigators also found that males read more literature about science and found mathematics more interesting than females, suggesting a possible relationship between interest and achievement.

Fennema and Sherman (1977) investigated mathematics achievement of males and females. The cognitive variables investigated included mathematics achievement, general ability, verbal ability, and spatial visualization. The affective variables investigated included stereotyping mathematics as a male domain, perceived attitudes of mother, father, and teacher toward student ability in mathematics, and usefulness of mathematics.

Mathematics achievement was measured by the Test of Academic Progress. General and verbal ability were evaluated using the Quick Word Test. The Space Relations Test of the Differential Aptitude Test was used as an instrument to evaluate spatial visualization. Affective variables were measured by the following tests: Attitude Toward Success in Mathematics, Mathematics as a Male Domain Scale, Mother Scale, Father Scale, Teacher Scale, and Effectance Motivation in Mathematics Scale. The affective variables were assessed by the Fennema-Sherman Mathematics Attitudes Scale. These scales were five point Likert-type, domain-specific scales. An analysis of variance was performed on the mathematics achievement scores using gender, school, and grade level as variables.

Students were tested in their classrooms by trained male and female administrators. Tests were administered according to standard instructions over four classroom periods. All students were given 40 minutes to complete the mathematics achievement test.

It was found that even though males scored higher on the mathematics achievement test, the difference was not significant. Data also did not support expectations that males are superior in mathematics achievement, spatial visualization, or the assumption that differences between the two genders increase with age and experience. Hypotheses were tested at the .05 α-level.

In a follow up study by Fennema and Sherman (1978), sex-related differences in mathematics achievement and related factors were considered. An ANOVA was performed on data for each of five mathematics variables, two cognitive variables, and eight affective variables with gender, grade, and area used as sources of variance. Significant area effects and gender-by-area interactions were found. As a result, ANOVAs were also performed on data for all variables in each area, with gender and grade used as sources of variance. Correlation coefficients between measures were computed for each sex and for the students combined over area and grade.

The results indicated no significant sex-related differences in mathematics achievement ($p < .05$). On the other hand, significant sex-related differences were discovered for confidence in learning mathematics and mathematics as a male domain ($p < .01$). This indicated that males were more confident in their ability to learn mathematics than females. It also indicated that males more commonly stereotype mathematics as a male domain than do females.

Benbow and Stanley (1980) examined the mathematical aptitude of males and females by studying data collected by the Study of Mathematically Precocious Youth (SMPY). This study utilized a t-test to determine significance.

Results indicated that males scored significantly higher ($p < .01$) than females in mathematical reasoning and on the mathematics section of the SAT. Males and females scored equally on the verbal section of the SAT. All students tested were in grade seven and had similar but not identical mathematics backgrounds. It should be noted that only highly motivated, mathematically able students were used in this study, affecting the true randomness of sample selection.

Armstrong (1981) reported results of two national surveys and used them to evaluate sex differences in mathematics achievement and participation. One survey was the Women in Mathematics Project and the other was from the second mathematics assessment conducted by the National Assessment of Educational Progress (NAEP).

Results of the Women in Mathematics Project suggested that significant differences among high school seniors favored males in problem-solving. On the other hand, thirteen-year-old females scored significantly higher than thirteen-year-old males on the computation and spatial visualization items. Results of the NAEP suggested that there were no significant differences found in computational skills and algebra skills between males and females of age seventeen. At this same age level, however, significant differences were found to favor males in the area of application skills. There were no significant differences suggested by the NAEP between boys and girls of age thirteen.

Differences in participation seemed to occur only at the high school level. The Women in Mathematics Project found that females tended to enroll in accounting or business mathematics while males enrolled in Algebra 2, trigonometry, probability and statistics, computer programming, and calculus. The NAEP also found that females often enrolled in general mathematics courses and consumer mathematics courses, while males took trigonometry, precalculus, and calculus courses.

All significant differences were determined at the .05 α-level with one exception. The differences that favored seventeen-year-old males over seventeen-year-old females in application skills was significant at the .01 α-level.

A study by de Wolf (1981) compared the amount of coursework in mathematics, quantitative ability, spatial ability, mechanical reasoning, and mathematics grade point average. The tests used in this study were taken from the Washington Pre-College Testing Program (WPC). The sample consisted of 2093 high school students, 962 of which were male, 1131 of which were female.

Statistical analysis for this study used two-tail t-tests and the .05 level of significance.

Results showed that sex differences in spatial ability and quantitative ability were at least partial reflections of differential mathematics training. It was discovered that male students took significantly more mathematics courses than did female students. Results also suggested that when females did enroll in mathematics courses, their GPAs tended to be significantly higher than those of male students.

When the amount of coursework was controlled, there were no significant differences between the sexes for the Quantitative Skills Test, A, the Mathematical Achievement subtest, and the Spatial Ability subtest. However, males did display greater scores on the Quantitative Skills Test, B, the Applied Mathematics subtest, and the Mechanical Reasoning subtest. In addition, even when coursework was not controlled, males still achieved greater success in these same three areas.

Stones, Beckmann, and Stephens (1982) completed a study designed to investigate differences in achievement of mathematics competencies among male and female college students enrolled in precalculus. The Beckmann-Beal Mathematical Competencies Test for Enlightened Citizens was the measurement instrument used. The test was given to students from four state colleges and six community colleges who were enrolled in classes categorized as College Algebra, Mathematics for Elementary Teachers, and Applied Mathematics. Statistics were analyzed using t-tests at the .05 and .01 levels of significance.

Results showed that males scored significantly higher in the categories of Geometry, Measurement, and Probability and

Statistics ($p < .01$) while females scored significantly higher in the category of Mathematical Reasoning ($p < .05$). There were no significant sex-related differences in achievement in the categories of Numbers and Numerals, Operations and Properties, Mathematical Sentences, Relations and Functions, Graphing, and Business and Consumer Mathematics.

In a study by Fulkerson, Furr, and Brown (1983), race, gender, and grade differences in mathematics achievement and expectations of success were investigated. Third, sixth, and ninth-grade students participated in tasks involving mathematics, geometry drawings, and mazes. Male and female black and white students were studied.

Two(gender) X 2(race) X 3(grade) analysis of variance were conducted by using adjusted sums of squares and least square means. Tests of simple effects were used for analyzing interactions. The level selected was $\alpha = .05$.

Results showed that boys and girls had equal expectations of success on all tasks at all grade levels. In addition, boys and girls did not differ significantly in achievement on any task or at any grade level. There were also no differences in achievement on any of the tasks between black and white students. There were no significant sex-related differences or race-related differences found when comparing students' expectations of success on all tasks. Ninth-grade students did outperform sixth-grade students who outperformed third-grade students as expected.

Senk and Usiskin (1983) conducted a study of geometry students designed to detect sex-related differences in the writing of geometry proofs. The test administered was of three forms, and data were reported separately by test form. Students took a geometry pretest, a proof writing test, and a standardized geometry achievement test along with part of a posttest.

Males outscored females on two forms of the test, and females outscored males on the third, but the differences were not significant. In addition, the male average number of proofs correct was greater than the female average. Again, this difference was not significant. Overall, no significant differences in sex-related achievement in the writing of geometry proofs could be detected. All data were tested at the .05 level of significance.

When an ANACOVA (using knowledge of geometry upon entering geometry as a variable) was performed on the proof total score, the adjusted mean total score for the females became higher than male adjusted mean total score. This was true for all three forms but was only significant on Form 3 (at the $\alpha = .05$ level). When the mean number of proofs correct were similarly adjusted, females again performed better than males on all forms, but not significantly so.

Wolleat, Becker, Pedro, and Fennema (1980) investigated high school students enrolled in college preparatory courses for sex-related differences in confidence and anxiety that could attribute for success or failure in mathematics achievement. Students were tested and surveyed for certain beliefs and attitudes. Included were the following: Belief that success is related to ability, belief that success is related to effort, belief that failure is related to ability (or lack thereof), and belief that failure is related to tasks being too difficult.

Statistics were analyzed using t-tests on the mean scores achieved by females and males on each of the tests. Multiple regression analysis was used to examine the relationships between gender, achievement, and attribution patterns. The resulting regression coefficients and the partial coefficients were tested for significance using an F-test.

Results showed that males tend to believe success is a result of ability while females tend to believe success is a result of effort. Females also tended to believe failure was a result of a lack of ability or a task being too difficult. These findings were significant ($p < .001$).

It was also found that as female students' achievement scores increased, so did their tendency to believe that effort affects their mathematics success. Thus, females with low achievement tended to believe effort has little to do with success. On the other hand, as achievement of males increased, the belief that success is a result of effort tended to decrease.

Leder (1980) conducted a study comparing performance of boys to performance of girls on mathematics tasks. Scores were taken from the HSC (Victorian Higher School Certificate) 1970-1979 to compare students receiving passing grades.

Results showed that in general, performance by male students was better than performance by female students, but no significant differences could be detected when comparing only those students receiving passing grades. In addition, each year males achieved a higher level than females when comparing those students receiving good grades (i.e. a grade of "A"). Leder also suggested that fear of success may have been a relevant factor in the sex-related differences in mathematics found.

Becker (1981) studied students' responses to the teacher in three different school systems in order to determine if teacher influence plays a role in mathematics achievement. Data were collected through observations of classroom behaviors as well as through interviews with teachers, administrators, guidance counselors, and students. Three male and seven female high school geometry teachers were observed.

The Brophy-Good Teacher-Child Dyadic Interaction System was the instrument used to analyze classroom behavior. Becker performed all 100 observations; however, a second observer was present at 11 observations to ensure accuracy. Scott's coefficient was used to asses inter-rater reliability. A consistency index of .84 was attained. Data were analyzed using ANOVA and tested using F-tests at the .05 and .01 levels.

Results of this study showed that significant differences occurred in favor of males in three observational categories. Males were more likely to receive feedback that sustained prolonged student-teacher interaction. Informal interaction between the teacher and the student occurred significantly more often with males than with females. Teachers were also more likely to use praise and criticism with male students. These were all significant ($p < .05$). Female students did tend to initiate interactions with the teachers more often than did male students, but not significantly.

In addition, the quality of student answers varied slightly in favor of males, but this difference was not significant. Females having equal ability as males also tended to receive better grades and did not require extra teacher attention. Expectations of achievement also varied by the gender of the student. It was also noted that parents' expectations of student achievement may have been a factor affecting their actual achievement. A common belief that mathematics is essential to the future of males but not to the future of females also surfaced in this study. This was noted in teacher behavior and language that reinforced the traditional view of mathematics as a masculine domain.

Parish and Wheatley (1973) performed an experiment designed to determine if the sex of the teacher would account for significant differences in performance of the second-grade student on operational length conservation items. Students were randomly divided into two groups.

The test consisted of nine items and were divided as follows: Items 1 and 2 were Practice items, Items 3 and 4 were Length Pretest items, Items 5 and 6 were Length Conservation items, Item 7 was a Response Breaker, and Items 8 and 9 were also Length Conservation items. Only students who answered

Items 1 and 2 correctly (Pretest items) were included in the study.

Data were analyzed using contingency tables. Data were tested using the X^2 test and the level of significance considered was the .05 level.

Results showed that for the male experimenter, there were a total of 7 conservers (4 male and 3 female) and 18 nonconservers (10 male and 8 female). For the female experimenter, there were a total of 15 conservers (6 male and 9 female) and 11 nonconservers (6 male and 5 female). The total number of conservers under the female experimenter was significantly greater than for the male experimenter, thus suggesting sex of the teacher is an important factor in the achievement of elementary students. In addition, male and female students did not appear to respond differently to a given test administrator.

Duval (1980) conducted a study to determine if gender and/or ability are related to grades assigned on a mathematics task. This was done by mailing 1,020 packets to teachers and asking them to participate by filling out questionnaires, reading profiles of students, and correcting examinations based on a set of given criteria. Of the 1,020 packets sent, only 315 were returned.

The experimental data were analyzed in an ANOVA technique for unequal cell sizes. Statistical tests used were the F-test and the t-test. The significance level used for each test was $\alpha = .05$.

Results showed that female students of average ability achieved the highest mean, suggesting that this group was being evaluated by a different set of standards than the high or low ability females. In addition, male students of low ability were evaluated using more lenient standards than those used to evaluate low ability females. Overall, the prediction that gender and/or ability would affect the grade received could not be supported by the data of this study.

Fennema and Tartre (1985) conducted a study designed to provide more information about the relationship between gender differences and mathematics achievement. This study investigated students of similar spatial and verbal abilities and how they used spatial visualization to solve word problems and problems involving fractions. Students in grades six, seven, and eight were studied.

Spatial visualization was measured by the Space Relations Portion of the Differential Aptitude Test. Verbal skills were measured by the Cognitive Abilities Test, Verbal Battery. The Mathematics Concepts Test measured sixth-grade mathematics Achievement. Eighth-grade mathematics achievement was measured by the Mathematics Basic Concepts (Level I, Form X) subtest of the Sequential test of Educational Progress. Data were analyzed using F-tests with significance levels of .05 and .01.

Results of this study indicated significant differences in favor of male students in the following areas: Word problems at the sixth-grade level, word problems for all three grades combined, total number of correct solutions at the sixth-grade level, and total number of correct solutions for all three grades combined. These were all significant ($p < .05$). When solving word problems, boys tended to have more mental movement and more picture information. On the other hand, girls were able to verbalize relevant information involved with solving problems more successfully than male students. Students with high spatial visualization skills did not outperform students with low spatial visualization skills. A pattern did arise suggesting students with high spatial visualization and low verbal skills were more able to create and use pictures in solutions to problems than students with low spatial visualization and high verbal skills.

Liben and Golbeck (1980) conducted a study that compared achievement of the sexes on tasks dealing with concepts of horizontality and verticality. Students in grades three, five, seven, nine, and eleven completed a nonphysical horizontality test, a physical horizontality test, a nonphysical verticality test, and a physical verticality test.

An analysis of variance was used as the mode of analysis and the F-test was used as the statistical test. Results were tested at the .01 level.

Results of the horizontality tests showed no significant relationship between gender and achievement of tasks. Similarly, results of the verticality tests showed no significant relationship between gender and achievement of tasks. Students' scores did tend to increase with each successive grade level as expected. Investigators also found student performance to be significantly better ($p < .01$) for the nonphysical tasks than for the physical tasks.

Moore and Smith (1987) studied data from the National Longitudinal Study of Youth Labor Force to determine the effects of sex, education, and ethnic groups on mathematics achievement. White, black, and Hispanic males and females were used in this study. The data dealing with the education variable was broken down into individuals completing grades K - 8, individuals completing eleventh grade, individuals completing grade twelve, and individuals completing one or more years of higher education. The last two education groups (completing high school and completing at least some higher education) were combined for analysis.

This study utilized a multivariate analysis of variance along with t-tests at various levels of significance. Data were chosen from a national probability sample of 11,914 men and women.

Results showed that as education increased, so did achievement in mathematics. Investigators also noted differences in average performance of ethnic groups. Whites generally outscored Hispanics who generally outscored blacks. In general, males tended to achieve higher than females belonging to the same ethnic group.

There also tended to be increased differences between the sexes in favor of males as the level of education increased. For individuals completing grades K - 8 only, females significantly outscored their male counterparts ($p < .0001$).

For those who have completed through grade eleven, there were no significant differences in achievement. Of those who have completed high school or some post high school education, males scored significantly higher than their female counterparts ($p < .01$).

There also appeared an increasing pattern of differentiation between the sexes in relation to performance on arithmetic reasoning items. For grades K - 8, there were no significant differences between the performances of males and females. For subjects completing grade eleven, males scores were significantly higher than female scores ($p < .001$). In addition, males significantly outscored females for those subjects completing grade twelve or higher ($p < .005$).

A study by Ethington and Wolfle (1984) re-examined reasons males and females differ in mathematics achievement. Information an data were taken from the study entitled "High School and Beyond." This study utilized LISREL to obtain maximum likelihood estimates of the covariance-structures model of mathematics achievement. The statistical test used was the X^2-test.

Results of this study showed that males achieved higher than females on a combined test of mathematics even after the effects of parental education, high school grades, spatial and perceptual abilities, attitudes toward mathematics, and exposure to mathematics courses had been controlled.

Other results showed that spatial ability had a positive influence on achievement in mathematics and males generally excelled in spatial ability. Perceptual ability was also found to influence mathematics achievement positively. In this category, there was a significant difference found in favor of females ($p < .01$).

A study by Monaco and Gentile (1987) was designed to determine if learned helplessness treatment would increase scores on mathematics tasks. It was also to designed to determine how learned helplessness interacts with the cognitive development level, strategy training, and gender.

In this study, students completed a test that labeled each as formal operational or concrete operational. Then, students completed tests dealing with pattern completion items (test I) and multiplication items (test II). Some students received helplessness training and an equal amount of students did not. Data from this study were analyzed using an analysis of variance and t-tests.

Results showed that the formal operational students scored significantly higher on both test I ($p < .001$) and test II ($p < .05$). Students who received training achieved higher levels of success on the pattern completion test. It was also found that males achieved significantly higher levels of success than females on both test I ($p < .01$) and test II ($p < .05$). The hypothesis that there would be a relationship between learned helplessness and gender, cognitive development level, and strategy training was not supported. It was also noted that helplessness treatment (or lack thereof) affected both males and females in similar ways.

CONCLUSIONS, RECOMMENDATIONS, AND LIMITATIONS

The literature reviewed on gender-related differences in mathematics achievement reported contradictory results. Many studies found that males significantly outperformed females in mathematics achievement, while other studies found females outperformed males. In addition, many studies did not find significant gender-related differences. There were also a number of variables left uncontrolled in many of the studies. One result indicated by such contradictory findings is the need for further study in the area of sex-related differences in mathematics achievement.

Most researchers agreed that there are many complex variables involved with sex-related differences in mathematics. Many researchers also believe there are biological or genetic factors that contribute to these differences, but they are too small to be considered as a major cause of differences in achievement. As a result, greater focus is placed on social, cultural, and environmental variables to explain sex differences in mathematical achievement. Some such variables are age, race, grade level, mathematical ability, verbal ability, anxiety toward mathematics, confidence, expectations of achievement, application skills, problem solving skills, spatial visualization, mathematical reasoning skills, participation in mathematics classes/courses, grade point average and overall ability of the student, beliefs that mathematics is related to effort or ability, level of education of the parents, attitudes toward mathematics of the parents, gender of the teacher, teacher attitudes and biases, stereotyping mathematics as a male domain, and many more. It should also be noted that many of these studies only considered some of these variables in conducting their research. As a result, some variables were left uncontrolled which, separately or in combination with others, could have produced faulty or incomplete results.

Many of the studies reviewed shared the conclusion that there is still a need for further research. Researchers also expressed the need for more complete control of variables which influence mathematics achievement so as to obtain more reliable data. Many of the studies also relied on data obtained through observations and/or surveys. Since the nature of these methods of research are subjective, results obtained have a high chance of being unreliable.

Other factors that must be considered are the many biases that may occur in conducting studies. Parent, teacher, and student biases certainly do occur, but are very difficult to measure or control. Biases may also (unintentionally) occur on the part of a researcher conducting a study. In addition, there may be biases in the language or format of tests favoring a certain gender, race, or group of students. As a result, great care must be taken in conducting research on such a topic.

In continuing to study sex-related differences in mathematics, one must be certain to maintain precise control over the many variable factors involved. If this is not possible, the results may not generalize beyond the sample population. Many of the subjects studied were mathematically talented, and there was a rather small variety of researchers involved. Thus, larger, more diverse sample populations should be considered, and further studies should be completed by a wider research base. Doing so would not only incorporate a larger variety of viewpoints in such studies, it would also increase the accuracy of results.

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