DOCUMENT RESUME

ED 160 445 SE 025 084

AUTHOR	Fennema, Elizabeth
TITLE	Sex-related Differences in Mathematics Achievement: Myths, Realities and Related Factors.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
PUB DATE	77
NOTE	33p.; Contains occasional light and broken type
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS	*Achievement; Curriculum; *Educationally Disadvantaged; Elementary Secondary Education; Learning Characteristics; *Mathematics Education; *Sex Differences; *Sex Role; *Sex Stereotypes

ABSTRACT

Many more males than females are involved in post high school mathematics study and in adult occupations that involve mathematics. This paper addresses the issue of whether this unequal representation of females and males is due to females' less adequate learning of mathematics or to deliberate choice of females not to study mathematics. After examining available studies relating to the matter, the paper concludes that when both females and males study the same amount of mathematics, differences in learning mathematics are minimal. Significantly fewer females elect to study mathematics and therein lies the problem. Factors contributing to this are females' lesser confidence in learning mathematics and belief that mathematics is not useful to them, males' belief that mathematics is a male domain, and teacher treatment of males and females. (MP)

Sex-related Differences in Mathematics Achievement: Myths, Realities and Related Factors*

Elizabeth Fennema

Department of Curriculum and Instruction
University of Wisconsin--Madison

Mathematics educators have used sex as a variable in research concerned with mathematics achievement for a number of years and many summaries of mathematics achievement have been published which include information about comparative learning of mathematics by females and males. Basically, all reviews published before 1974 concluded that while there might not be a sex-related difference in mathematics achievement in young children, male superiority was always evident by the time learners reached upper elementary or junior high school. In addition, males were definitely superior on higher level cognitive tasks. E.g., "The evidence would suggest to the teacher that boys will achieve higher than girls on tests dealing with mathematical reasoning" (Glennon and Callahan, 1968, p. 50). "From junior high school and beyond . . . boys now surpass girls in studies involving science and mathematics" (Suydam & Riedesel, 1969, p. 129). "Sex differences in mathematical abilities are of course, present at the kindergarten level and undoubtedly earlier" (Aiken, 1971, p. 203).

The literature reviews published since 1974 do not show the same concensus about male superiority that was evident previously. In a 1974 review which synthesized information from 36 studies, the conclusion was that there were no sex-related differences in elementary school children's

*Portions of the manuscript were prepared under a grant from the National Institute of Education.

mathematics achievement, and little evidence that such differences exist in high school learners. However, there was some indication that males excelled in higher level cognitive tasks and females in lower level cognitive tasks (Fennema, 1974). Callahan & Glennon (1975) agreed with this conclusion while Maccoby and Jacklin (1974) in a highly quoted review disagreed. They stated that one "sex difference that [is] fairly well established . . . is that boys excel in mathematical ability" (p. 351-352). From these reviews it is evident that currently there is not concensus on whether sex-related differences in mathematics achievement exists.

The question of whether or not there are sex related differences in mathematics is more complicated than it first appears. While there is no doubt that many more males than females are involved in post high school mathematics study and in adult occupations that involve mathematics, what has been unclear is whether this unequal representation of females and males in post high school studying and using of mathematics is due to females' less adequate learning of mathematics or to deliberate choice by females not to study mathematics. Both of these issues will be addressed here.

Sex-related Differences in Mathematics Achievement

In order to clarify the reality of sex-related differences in mathematics achievement, four major studies of sex-related differences in mathematics achievement will be specifically noted: Project Talent, the National Longitudinal Study of Mathematical Abilities (NLSMA), the National Assessment of Educational Progress (NAEP), and the Fennema-Sherman studies. In

addition, some studies from other cultures will be briefly reviewed as well as the Stanley study of mathematically precocious youth and scores on college entrance examinations.

Data for Project Talent were gathered about 1960 (Flanagan et al., 1964). This study assessed the mathematics achievement (among many other things) of a random sampling of high school students in the United States (n = 440,000). The data indicated that in grade 9 sex-related differences in mathematics achievement were neglibible but by 12th grade males tended to do better. The mean difference at the 12th grade, while statistically significant, appears to have little educational significance (approximately one item). No attempt was made to control the number of mathematics courses subjects had taken previously. Higher percentages of males than females were enrolled in college preparatory courses so males undoubtedly had taken more mathematics courses and males were more apt to say they were preparing for a career which needed mathematics. Undoubtedly a population of males with more mathematical background was being compared with a population of females with less mathematical background.

In 1975 a follow up to the 1960 Project Talent study was done. Data were collected from approximately 1800 students in grades 9-11 in seventeen of the original schools (Flanagan, 1976). After careful statistical checks on reliability of the comparisons and adjustments for any change in school SES the following were concluded: (See Table 1). 1) While the mathematics test scores were fairly stable from 1960 to 1975, the differences between females and males had been reduced. 2) On computation tasks, male scores had declined 17% and female scores 11% with the female mean score being 8.2 points higher than the male mean score.

3) Quantitative reasoning scores declined 8% for each sex with females scoring .6 of an item lower in 1975. It is difficult, after carefully examining these data from Project Talent, to conclude that males' mathematics achievement was much higher than that of females in 1960 or 1975.

Support for the belief that females do not achieve as well as males in mathematics could come from the NLSMA data which were gathered during 1962-67. In these multitudinous studies, sex was used as a control variable. Analyses were done independently by sex whenever significant sex by any other variable interaction was found. Unfortunately, the results from these studies have been inadequately reported and interpreted making the knowledge they could contribute to the area under consideration largely unavailable. However, a summary statement says: "Differences favoring girls were for variables at the comprehension level (the lowest cognitive level tested) and the differences favoring the boys were for variables at the application and analysis level" (Wilson, 1972, p. 94). The directors of this federally financed program abrogated their responsibility to females when they followed the above remarks with this statement: "Interpretation and comment on this pattern will be left to persons involved in the women's liberation movement" (Wilson, 1972, p. 95). The number of mathematics courses which had been taken previously by the subjects in the NLSMA studies was controlled so the conclusion reached undoubtedly was statistically valid in 1967. What is unknown is the size of the differences between the mean female and male performance scores and the educational significance of that difference.

Results from the 1972-73 mathematics data collection of the National

Table 1

PROJECT TALENT*

Comparisons of 1960 and 1975 Mathematics Results

	MALES			FEMALES		
	Raw Score 1960	Raw Score 1975	Tenth Grade %ile Difference	Raw Score 1960	Raw Score 1975	Tenth Grade %ile Difference
QUANTITATIVE REASONING	8.5	7.8	-8%	8.0	7.2	-8%
MATHEMATICS	10.5	10.7	+2%	9.9	10.3	+3%
COMPUTATION	25.7	18.7	-17%	30.8	26.9	-11%

*Abstracted from: Flanagan, J. C. Changes in school levels of achievement: Project TALENT ten and 15 year retests. Educational Researcher, 1976, 5(8), 9-12.

Assessment of Educational Progress (NAEP) has received much publicity and one sentence has been widely quoted: "In the mathematics assessment, the advantage displayed by males, particularly at older ages can only be described as overwhelming" (Mullis, 1975, p. 7). Inspection of these data (Table 2) confirms that males did outperform females at ages 17 and 26-35. However, at ages 9 and 13 differences were minimal and sometimes in favor of females. The problem of comparable populations is a concern here also. The population was selected by sophisticated random sampling techniques with no control for educational or mathematical background. Since males have traditionally studied mathematics more years than have females, once again a population of males with more background in mathematics was being compared with a population of females with less background in mathematics. At ages 9 and 13 when the educational and mathematical background was similar, the achievement of both sexes was also similar.

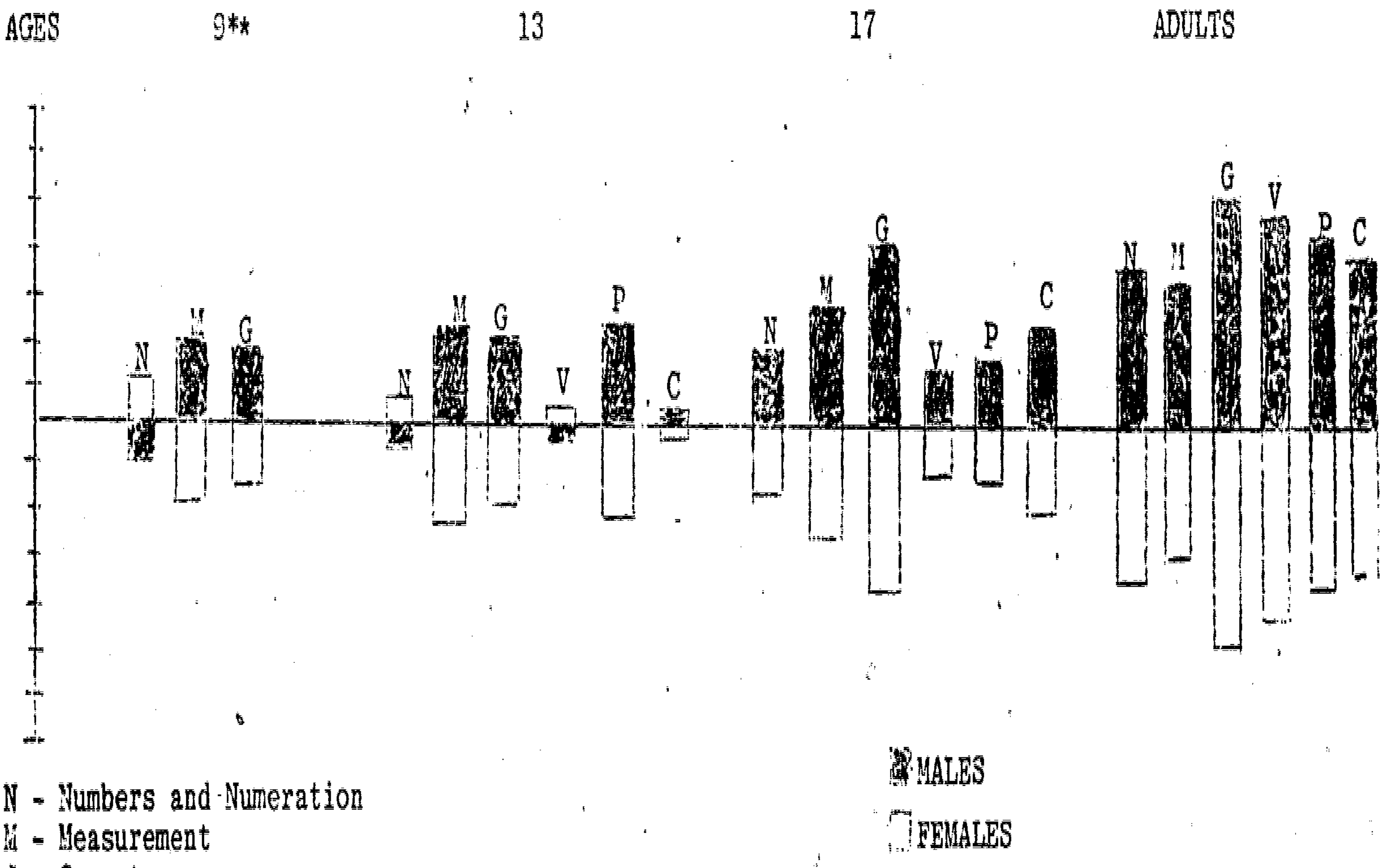
The Fennema-Sherman Study, data for which were collected in 1975-76, investigated mathematics achievement in grades 6-12. (Fennema and Sherman, 1977; Sherman and Fennema, 1977; Fennema and Sherman, 1978). This National Science Foundation sponsored study investigated a variety of levels of mathematics learning as well as cognitive and affective variables hypothesized to be related to differential mathematics achievement by females and males. The results of this study have wide generalizability because of the diverse, carefully selected sample. In grades 9-12 ($\underline{n}$ = 1233) with subjects whose mathematics backgrounds were carefully controlled, significant differences in achievement in favor of males (approximately two items) were found in two of four schools. In grades 6-8 ($\underline{n}$ = 1330) significant differences were found in favor of females in a low cognitive level

Table 2

MEDIAN DIFFERENCE IN PERFORMANCE

BETWEEN MALES AND NATION AND FEMALES AND NATION ON

MATHEMATICS CONTENT AREAS*



N - Numbers and Numeration
M - Measurement
G - Geometry
V - Variables and Relationships
P - Probability and Statistics
C - Consumer Math

**National Mean

*Mullis, I. V. S. Educational achievement and sex discrimination. Denver, Colorado: National Assessment of Educational Progress, 1975.

mathematical task in one of four tested school areas. In another of the four school areas significant differentes were found in favor of males in a high cognitive level mathematical task.

One other measure of mathematics achievement should be noted, the differential evident between the sexes on the SAT (Scholastic Aptitude Test), a college entrance examination. Normally administered to high school seniors, it has a Verbal Component and a Mathematics Component. According to the publishers of the test, the mathematics required is that which is taught in grades 1-9. Women have, over a period of years, scored lower than men on this test. However, a look at some trends is interesting. "In 1960 the mathematical component means were 465 for women, 520 for men. Twelve years later, the average for women was virtually unchanged, but the average for men had dropped by 14 points (to 506)" (Wirtz, 1977, p. 16). Although the Advisory Panel appointed to review the SAT score declines (Wirtz, 1977) concludes that one reason the scores declined from 1962-1970 was that more women were taking the test, the data do not confirm that women's scores dropped.

Once again, however, conclusions about male superiority are being drawn from populations which have studied different amounts of mathematics. Even though the mathematics required for the SAT may be taught before disparity in enrollment between the sexes is evident, continued use of such mathematics in advanced high school classes undoubtedly aids one in solving items of the type included in the SAT.

A different perspective on sex-related differences in mathematics achievement is noted if one examines performances of highly precocious males and females. In the Stanley Study of Mathematically Precocious Youth,

many males outperformed any female. E.g. in the 1973 talent search junior high school youth who had scored above the 98th percentile on previously given subtests of standardized achievement tests were asked to volunteer to be tested on a college entrance examination. Seven percent of the boys scored higher than any girl and the boys' mean score was significantly higher than the girls' mean score (Fox, 1976).

In summary what can be concluded about sex-related differences in mathematics learning in the United States in 1978: 1) There are no sex-related differences evident in elementary school years. This is at all cognitive levels from computation to problem solving. This conclusion has been accepted for a number of years. 2) After elementary school years, differences do not always appear. 3) Starting at about the 7th grade, if differences appear, they tend to be in the males' favor, particularly on tasks involving higher level cognitive skills. 4) There is some evidence that sex-related differences in mathematics learning in high schools may not be as large in 1978 as they were in previous years. 5) Conclusions reached about male superiority have often been gathered from old studies or studies in which the number of mathematics courses taken was not controlled. Therefore, a better mathematically educated group of males was being compared to a group of females who had participated in less mathematics education. In reality, what was being compared were not females and males but students who had studied mathematics 1-3 years in high school with students who had studied mathematics 2-4 years in high school.

An examination of cross cultural differences in mathematics performance is interesting. In Australia, female superiority on problem solving and

computation tasks in grades 5-8 is reported while males performed at high levels in space tasks (Clements and Watanawaha, 1977). However, Keeves (1973) reports that male superiority over females in mathematics achievement was found within all ten countries which participated in the First International Study of Educational Achievement.

Sex-related Differences in the Studying of Mathematics

There are sex-related differences in the studying of mathematics. This is indicated by females choosing not to enroll in mathematics courses in high school and by the paucity of females in university mathematics courses. Undoubtedly, the most serious problem facing those concerned with equity in mathematical education for the sexes is ensuring that females continue their study of mathematics. In support of this statement consider some data from Wisconsin. During the 1975-76 academic year, while approximately the same number of females and males were enrolled in Algebra, in the advanced courses many more males were enrolled (see Table 3).

Although only symptomatic of the effects of many variables, electing not to study mathematics in high school beyond minimal or college requirements is the cause of many females' nonparticipation in mathematics related occupations. The one variable which can be positively identified as causing sex-related differences in mathematics learning is the differential number of years females and males spend formally studying and using mathematics. Such a simplistic explanation of such an important problem seems too good to be true. However, this author believes strongly that if the amount of time spent learning mathematics is somehow equated for females and males, educationally significant sex-related differences in mathematics performance will disappear.

Table 3[c]

Number of Males and Females Enrolled in Wisconsin in Mathematics Courses[a]

COURSE	MALES	FEMALES
Algebra[b]	41,404	41,579
Geometry	20,937	20,280
Algebra II	11,581	9,947
Pre-Calculus	3,234	1,917
Trigonometry	4,004	2,737
Analytic Geometry	1,752	970
Probability/Statistics	1,113	581
Computer Mathematics	3,396	1,481
Calculus	611	262

[a] Data obtained from Wisconsin Department of Public Instruction Enrollment Statistics, 1975-76.

[b] Students enrolled in one year course and two year course.

[c] Konsin, M. A. Enrollment in Wisconsin high school mathematics classes by sex during 1975-76. Unpublished manuscript, University of Wisconsin-Madison, 1977.

Related Factors

While it is interesting to know about comparative mathematics achievement of females and males, it is more important to gain understanding of why so many males leave educational institutions knowing a great deal more mathematics than females know. In order to gain this understanding selected cognitive, affective and educational variables will be discussed.

Cognitive Variables

"Mathematics is essentially cognitive in nature; and the principle, distinguishing goals or objectives of mathematics instruction are (and should be) cognitive ones" (Weaver, 1971, p. 263). Since mathematics is a cognitive endeavor, the logical place to begin to look for explanatory variables of sex-related differences in mathematics performance is in the cogntive area. It is within this area that the most important variable can be found, i.e., the amount of time spent studying mathematics. This variable and its impact has already been discussed.

Spatial Visualization

Another cognitive variable that may help explain sex-related differences in mathematics is spatial visualization--a particular subset of spatial skills. Spatial visualization involves visual imagery of objects, movement by the objects themselves or change in their properties. In other words objects or their properties must be manipulated in one's "mind's eye"--or mentally. Even though the existence of many sex-related differences is currently being challenged, the evidence is still persuasive that in the American culture male superiority on tasks that require spatial visualization is evident beginning during adolescence (Fennema, 1975;

Maccoby & Jacklin, 1974). However, even this difference appears to be moderating.

The relationship between mathematics and spatial visualization is logically evident. In mathematical terms spatial visualization requires that objects be (mentally) rotated, reflected and/or translated. These are important ideas in geometry. In fact James and James (1968) in defining geometry as "the science that treats of the shape and size of things . . . the study of invariant properties of given elements under specified groups of transformation" (p. 162) are describing accurately most conditions which are met by items on spatial visualization tests.

Many mathematicians believe that all of mathematical thought involves geometrical ideas. The total discipline of mathematics can be defined as the language for describing those aspects of the world which can be stated in terms of "configurations" (Bronowski, 1947). Meserve (1973) believes that each person who makes extensive use of all areas of mathematics uses the modes of thought of geometry at every turn and that "even the most abstract geometrical thinking must retain some link, however attenuated, with spatial intuition" (p. 249). In the Russian literature, mathematics and spatial abilities are regarded as inseparable (Kabanova-Meller, 1970). Therefore, if spatial visualization items are geometrical in character and if mathematical thought involves geometrical ideas, spatial visualization and mathematics are inseparately intertwined.

Not only are spatial visualization activities similar to ideas within the structure of mathematics, but spatial representations are being increasingly included in the teaching of mathematics. E.g., the Piagetian

conservation tasks, which are becoming a part of many pre-school programs, involve focusing on correct spatial attributes before quantity, length, and volume are conserved. Most concrete and pictorial representations of arithmetical, geometrical and algebraic ideas appear to be heavily reliant on spatial attributes. The number line, which is used extensively to represent whole numbers and operations on them, is a spatial representation. Commutativity of multiplication illustrated by turning an array 90 degrees, involves a direct spatial visualization skill. Many other examples could be cited.

Although the relation between the content of mathematics and spatial visualization skills appears logical, results from empirical studies which have explored the relationship are not consistent. Many factor analytic studies have explored this relationship and several authors have reviewed the literature. Some investigators have definitely concluded that spatial skills and learning of mathematics are not related. In 1967, Very concluded: "Research on spatial ability has failed to produce any significant correlation of (the spatial factor) with any facet of mathematics performance" (p. 172). Fruchter (1954) stated that "spatial ability is unrelated to academic performance with the possible exception of a few very specialized courses such as engineering drawing" (p. 2). Smith (1964) concluded that although "there are several studies which indicate consistently that spatial ability is important in tests which are genuinely mathematical as distinct from those which involve purely mechanical or computational processes . . . the question whether the mathematical ability is dependent on the visual factor (or factors) has not been definitely answered" (pp.127, 64).

Even in geometry where one would expect to find the strongest relationship, empirical findings do not indicate clearly that the two are related. Lim concluded in 1963 after a thorough review of relevant literature that the evidence for a relationship between geometric ability and spatial visualization was inconsistent and unreliable. Werdelin (1971) was not willing to conclude definitely that spatial visualization ability and geometry ability were related. However, he felt that "there is strong pedagogical reason to believe in a connection between the ability to visualize and geometric ability" (p. 39).

Other authors feel that data indicate a positive relationship. In 1951, Guilford, Green and Christensen concluded that spatial visualization ability helped in solving mathematics problems. French (1951, 1955) showed that successful achievement in mathematics depends to some extent on use of spatial visualization skills. In a more recent review, Aiken (1973) concluded that spatial-perceptual ability was one of the "most salient" mathematical factors extracted in various investigations. Obviously, the relationship between learning in mathematics and spatial ability is not clear and the need for more data is great.

Even less is known about the effect that differential spatial visualization has on the mathematics learning of females and males. Indication that the relationship between the learning of mathematics and spatial visualization is an important consideration, is the concurrent development of sex-related differences in favor of males in mathematics achievement and spatial visualization skills. No significant sex differences in either mathematics achievement or spatial visualization skills have been consistently reported in subjects 4-8 years old. Sex differences

in performance on spatial visualization tasks become more pronounced between upper elementary years and the last year of high school (Maccoby & Jacklin, 1974). Sex differences in mathematical achievement that do exist also appear during this time span (Fennema, 1974). Perhaps less adequate spatial visualization skills may partially explain sex-related differences in achievement in mathematics.

However, the Fennema-Sherman study specifically investigated the relationship between mathematics achievement and spatial visualization skills. These data do not support the idea that spatial visualization is helpful in explaining sex-related differences in mathematics achievement. In this study of females and males (grades 6-12) enrolled in mathematics courses, few sex-related differences in either mathematics achievement or spatial visualization skills were found. The two were related ($r \approx .5$) similarly for both sexes and spatial visualization appeared to influence both females and males equally to continue studying mathematics.

Affective Variables

The Confidence-Anxiety Dimension in Mathematics

One tends to do those things one feels confident to do and to avoid activities which arouse anxiety. This confidence-anxiety dimension, as it relates to mathematics learning, is one of the more important affective variables that helps explain sex-related differences in mathematics learning. The relationship of anxiety and mathematics learning has been explored by a variety of methodologies and with instruments purported to measure debilitative or facilitative anxiety in general and/or specific to mathematics. Callahan and Glennon (1975) conclude that "anxiety and mathematics are related. In general high anxiety is

associated with lower achievement in mathematics" (p. 82). Reports from NLSMA indicate that across grades 4-10 decreases in facilitating anxiety appeared, with females' scores decreasing more than males' scores. Debilitating anxieties increased for females during these grade levels (Crosswhite, 1975).

Confidence per se has not been given specific attention as it relates to mathematics except in the Fennema-Sherman study. However, self-concept, which appears to be defined in many scales as self confidence, has received much study. Leviton (1975) and Primavera et al. (1974) reviewed the literature dealing with self-concept and both concluded that a positive relationship exists between academic achievement and self esteeem. Brookover and Thomas (1964) offer evidence that self concept is not generalizable but related to specific academic areas. Callahan and Glennon conclude that there is a positive relationship between self-esteem and achievement in mathematics. Others have also recognized the importance of academic self concept in learning mathematics (Bachman, 1970; Fink, 1969).

Although both confidence and anxiety have been defined as separate traits, it appears in relation to mathematics, they are very similar. In the Fennema-Sherman study an attempt was made to measure both confidence and anxiety. A high rating on the confidence scale correlated highly (r = .89) with a low rating on the anxiety scale. While it may be possible to talk about the two independently it doesn't appear to be useful.

The literature strongly supports the fact that there are sex-related differences in the confidence-anxiety dimension. It appears reasonable

to believe that lesser confidence, or greater anxiety on the part of females is an important variable which helps explain sex-related differences in mathematics studying. Crandall et al. (1962) concluded that girls underestimate their own ability to solve mathematical problems. Others have concluded that females feel inadequate when faced with a variety of intellective, problem solving activities (Kagan, 1964). Maccoby & Jacklin (1973) reported that "girls tend to underestimate their own intellectual abilities more than boys do" (p. 41).

In the Fennema-Sherman study, at each grade level from 6-12, boys were significantly more confident in their abilities to deal with mathematics than were girls. In most instances this happened when there were no significant sex-related differences in mathematics achievement. In addition, confidence in learning mathematics and achievement were more highly correlated than any other affective variable and achievement (r = .40). Confidence was almost as highly related to achievement as were the cognitive variables of verbal ability and spatial visualization.

Stereotyping Mathematics as a Male Domain

It is commonly accepted that mathematics is stereotyped as an activity more appropriate for males than for females. It has been believed that the sex typing of mathematics as male starts in the elementary school, becomes stronger during adolescent years and is solidified as a male domain by adult years. However, Stein and Smithells (1969) and Stein (1971) provide evidence that mathematics is not considered masculine by females and males until adolescent years and even during these years is not ranked as highly masculine as are spatial, mechanical and athletic tasks. Bobbe (1971) found that with fourth and sixth grade subjects,

arithmetic was judged to be feminine by girls while boys judged it to be appropriate for both sexes. In the adult world, it is a fact that the use and creation of mathematics is predominantly a male domain. Stein and Smithells (1969) offered evidence that in 12th grade, females perceived this fact and were responding to the reality.

The Fennema-Sherman study indicated that females in grades 6-12 deny that mathematics is a male domain. While the males in the study did not strongly stereotype mathematics as a male domain, at each grade they stereotyped it at significantly higher levels than did females. This is an interesting and highly significant finding. The cross sex influence on all aspects of behavior is strong during adolescent years. Since males stereotype mathematics as a male domain, they undoubtedly communicate this belief in many subtle and not so subtle ways to females which influences females willingness to study mathematics. This has strong implications for the development of intervention programs designed to increase females' participation in mathematics.

<u>Usefulness of Mathematics</u>

A different kind of affective variable is belief in the personal usefulness of mathematics. Hilton and Berglünd (1974) and the Fennema-Sherman study provided data indicating that females to a lesser degree than males believe that mathematics is personally useful. However, the difference between female and male beliefs about the usefulness of mathematics was not as great in the Fennema-Sherman study as it was in the Hilton-Berglünd study. This may indicate that the beliefs of females are becoming more similar to males in this aspect.

Effectance Motivation in Mathematics

One variable, which has been hypothesized to show a sex-related difference, is effectance motivation. This motive can be "inferred specifically from behavior that shows a lasting formalization and that has characteristics of exploration and experimentation" (White, 1959, p. 323). It is closely related to problem solving activity and is often called intrinsic motivation. This motivation would encourage learners to participate in mathematical activities at high cognitive levels. Some believe that females are not so involved in problem solving activites as are males (Carey, 1958; Kagan, 1964). However, the Fennema-Sherman study found no sex-related difference in this variable at any grade level from 6-12. It appears that belief that females are not as intrinsically motivated as males in mathematics is merely a myth.

Educational Variables

There are sex-related differences in the final outcome of mathematical education due in large part to females' reluctance--if not refusal--to elect to study mathematics. Some intervention is essential at the present time to ensure equity in mathematical education for both sexes. However, before effective intervention can be planned, more information is needed about critical school variables which are amenable to change and important in the educational process.

Teachers

Teachers are the most important educational influence on students' learning of mathematics. From kindergarten to high school, learners spend thousands of hours in direct contact with teachers. While other educational agents may have influence on educational decisions, it is the day

by day contact with teachers which is the main influence of the formal educational institution. Part of the teachers' influence is in the learners' development of sex role standards. These sex role standards include definitions of acceptable achievement in the various subject areas. It is believed that this influence by teachers is exerted through differential treatment of the sexes as well as expectations of sex-related differences in achievement.

Schonborn (1975) concluded that many studies have indicated teachers treat female and male students differently. In general, males appear to be more salient in the teachers' frame of reference. Teachers' interaction with males is greater than it is with females in both blame and praise contacts. Teachers also reinforce in both females and males sexually stereotypic behavior deemed appropriate for their sex (Sears and Feldman, 1966). Brophy, Good and their colleagues have been the major investigators of teacher treatment of females and males with their main interest being teachers' treatment of males. In several studies they have concluded that girls and boys receive equal treatment. However, the data from one of their major studies shows that while the sex of the teacher was unimportant, high achieving high school boys received significantly more attention in mathematics class than any other group (Good, Sikes & Brophy, 1973). Another study involving first grade reading replicated this trend at nonsignificant levels (Good and Brophy, 1971). Their conclusion from these studies is that teacher bias was not evident. One must question why no conclusion was reached about inequitable treatment of high achieving females.

The investigation of the relationship between teacher behavior and

sex related difference in mathematics appears to be crucial to understanding why females do not participate at higher levels in mathematics. In particular information in these areas would be helpful: 1) What are the effects of differential teacher treatment and expectations on achievement and election of mathematics courses? 2) Do teachers differentially reinforce males and females for specific kinds of mathematical and or sexually stereotypic activities? Are males being reinforced more for problem solving activities while females are reinforced for computational activities? 3) What is the effect of sex of teacher on mathematical achievement of boys and girls? While O'Brien (1975) reports no sex of teacher effect, Good, Sikes and Brophy (1973), and Shinedling and Pedersen (1970) report that male students do best in quantitative scores when taught by male teachers.

School Organization

There is some evidence and much belief that schools do influence sexual stereotypes. Minuchin (1971) concluded that children who attended schools categorized as traditional or modern differed in their sex-typed reactions. The interaction of the sexes was different in those schools, also. In the most traditional school boys became leaders in problem solving while girls became followers. This was not so in the less traditional schools. The sex role behavior of children attending traditional schools was more rigid than children attending liberal schools.

Some schools are remarkably more effective in persuading females to attempt high achievement in mathematics. Casserly (1975) identified 13 high schools which had an unusually high percentage of females in advanced

placement mathematics and science classes. She concluded that the schools had identified these girls as early as fourth grade and the school teachers and peers were supportive of high achievement by the females. Rowell (1971) pursued the same type of investigation in attempting to identify schools and their characteristics which produced high achieving females in science. Studies identifying and describing those schools which are particularly successful in encouraging females to enroll in mathematics beyond minimal requirements should be done.

Many are advocating that female only classes will result in equity in mathematical education. The argument for this type of school organization goes something like this. Because peer pressure against female competitiveness is too strong a force, females will not compete against males in mixed sex classrooms. Female leadership (in problem solving in this case) is only able to emerge when competition with males is eliminated. Teachers will not have different sex-related expectations and behaviors if only one sex is present. Single sex classrooms appear to provide a simple solution to a complex problem. However, the weight of evidence found does not support this type of grouping. Conway (1973) convincingly argues that throughout history separate education for the sexes has resulted in inferior educaton for females. Keeves, (1973) after a careful and thorough review of mathematics and science education in 10 countries, concluded that the "extent to which a community provides for education in single sex schools would appear to indicate the extent to which it sees its boys and girls requiring different preparation for different societal roles" (p. 62). He argues that "in so far as a community has different expectations for different groups of its members and proceeds

to mould its future members through different organizations, then it fails to provide equal opportunities for individual development" (p. 52). In an unreported study comparing attitudes of 10th grade females who had spent most of their educational lives in single or mixed sex classrooms, females from the mixed sex classrooms exhibited significantly more positive attitudes toward mathematics (Fennema-Meyer, 1976).

Before single sex classrooms are embraced as a panacea for females' educational equity, careful examination must be done concerning long term effectiveness of such programs. In reality, this may be a partially non-researchable problem. No one can foresee the implications for females 50 years from the present time of being isolated in their mathematical training. Because of what has happened to females as well as blacks over the last century, single sex classroom school organization must be approached with caution.

Conclusions

What then, can be said that is known about sex related differences in mathematics, and factors related to such differences? Certainly, when both females and males study the same amount of mathematics, differences in learning mathematics are minimal and perhaps decreasing. Many fewer females elect to study mathematics and therein lies the problem. Factors which appear to contribute to this nonelection are females' lesser confidence in learning mathematics and belief that mathematics is not useful to them and males' belief that mathematics is a male domain. In addition differential teacher treatment of males and females is important.

There is nothing inherent (Sherman, 1976) which keeps females from learning mathematics at the same level as do males. Intervention programs

can and must be designed and implemented within schools which will increase females' participation in mathematics. Such programs must include male students, female students and their teachers. Only when such intervention programs become effective can true equity in mathematics education be accomplished.

References

Aiken, L. R. Intellective variables and mathematics achievement: Directions for research. Journal of School Psychology, 1971, 9, 201-209.

Aiken, L. R. Ability and creativity in math. Review of Educational Research, 1973, 43, 405-432.

Bachman, A. M. The relationship between a seventh-grade pupil's academic self-concept a. d achievement in mathematics. Journal for Research in Mathematics Education, 1970, 1, 173-179.

Bobbe, C. N. Sex-role preference and academic achievement (Doctoral dissertation, Yeshiva University, 1971). Dissertation Abstracts International, 1971, 32B, 1818-1819.

Brookover, W. B., & Thomas, S. Self concept of ability and school achievement. Sociology of Education, 1964, 37(3), 271-279.

Brownowski, J. Mathematics. In D. Thompson & J. Reeves (Eds.), The quality of education. London: Muller, 1947.

Callahan, L. G. & Glennon, V. J. Elementary school mathematics: A guide to current research. Washington, D. C.: Association for Supervision and Curriculum Development, 1975.

Carey, G. L. Sex differences in problem-solving performance as a function of attitude differences. Journal of Abnormal and Social Psychology, 1958, 56, 256-260.

Casserly, P. L. An assessment of factors affecting female participation in Advanced Placement Programs in mathematics, chemistry, and physics (Grant No. GY - 11325). Washington, D. C.: National Science Foundation, July 1975.

Clements, M. A. & Wattanawaha, N. Sex and age-within-grade differences in mathematical achievement of Victorian children. In M. A. Clements & J. Foyster (Eds.) Research in Mathematics Education, 1977, 2, Melbourne, Australia.

Conway, J. K. Perspectives on the history of women's education in the United States. In Perspectives on female education. Symposium presented to the annual meeting of the American Educational Research Association, New Orleans, 1973.

Crandall, V. J., Katkovsky, W., & Preston, A. Motivational and ability determinants of young children's intellectual achievement behaviors. Child Development, 1962, 33, 643-661.

Crosswhite, F. J. Correlates of attitudes toward mathematics. NLSMA Report No. 20. Abstracted by L. R. Aiken, Investigations in Mathematics Education, 1975, 8(3), 38-40.

Fennema, E. Mathematics learning and the sexes: A review. Journal for Research in Mathematics Education, 1974, 5, 126-139.

Fennema, E., & Meyer, R. A. Attitudes toward mathematics held by females educated in single sex or coed schools. Manuscript in preparation, 1976.

Fennema, E., & Sherman, J. A. Sex-related differences in mathematics achievement, spatial visualization and affective factors. American Educational Research Journal, 1977, 14(1), 51-71.

Fennema, E., & Sherman, J. Sex-related differences in mathematics achievement and related factors: A further study. Journal for Research in Mathematics Education, 1978, 9(3), 189-203.

Fink, M. B. Self-concept as it relates to academic underachievement. California Journal of Educational Research, 1969, 13, 57-61.

Flanagan, J. C., Davis, F. B., Daily, J. T., Shaycoft, M. F., Orr, D. B., Goldberg, I., & Neyman, C. A. The American high-school student. Pittsburgh: University of Pittsburgh, 1964.

Flanagan, J. C. Changes in school levels of achievement: Project TALENT ten and fifteen year retests. Educational Researcher, 1976, 5(8), 9-12.

Fox, L. H. Sex differences in mathematical precocity: Bridging the gap. In D. P. Keating (Ed.), Intellectual talent: Research and development. Baltimore: Johns Hopkins University, 1976.

French, J. W. The West Point tryout of the guidance battery. (Research Bulletin 51-12) Princeton: Educational Testing Service, 1951. (Psychological Review, 1967, 74, 290-299).

French, J. W. The West Point tryout of the guidance battery, part 2. (Research Bulletin 55-6) Princeton: Educational Testing Service, 1955. (Psychological Review, 1967, 74, 290-299).

Fruchter, B. Measurement of spatial abilities: History and background. Educational and Psychological Measurement, 1954, 14, 387-395.

Glennon, V. J., & Callahan, L. G. A guide to current research: Elementary school mathematics. Washington, D. C.: Association for Supervision and Curriculum Development, 1968.

Good, T., & Brophy, J. E. Questioned equality for grade one boys and girls. The Reading Teacher, 1971, 25, 247-252.

Good, T. L., Sikes, J. N., & Brophy, J. E. Effects of teacher sex and student sex on classroom interaction. Journal of Educational Psychology, 1973, 65, 74-87.

Guilford, J. P., Green, R. F., and Christensen, P. R. A factor analytic study of reasoning abilities. II. Administration of tests and analysis of results. Report No. 3, 1951. University of Southern California, Psychology Laboratory. (Psychological Review, 1967, 74, 290-299).

Hilton, T. L., & Berglund, G. W. Sex differences in mathematics achievement - A longitudinal study. Journal of Education Research, 1974, 67, 231-237.

James, A., & James, R. C. Mathematics Dictionary, (3rd ed.). Princeton: Van Nostrand, 1968.

Kabanova-Meller, E. N. [The role of the diagram in the application of geometric theorems]. In J. Kilpatrick and I. Wirszup (Eds.), and M. Ackerman (trans.). Soviet studies in the psychology of learning and teaching mathematics, (Vol. IV). Stanford, California: School Mathematics Study Group, Stanford University and Survey of Recent East European Mathematical Literature, University of Chicago, 1970. (Originally published, 1950).

Kagan, J. Acquisition and significance of sex typing and sex role identity. In M. L. Hoffman and L. Hoffman (Eds.), Review of Child Development Research. New York: Russell Sage Foundation, 1964.

Keeves, J. P. Differences between the sexes in mathematics and science courses. International Review of Education, 1973, 19, 47-63.

Konsin, M. A. Enrollment in Wisconsin high school mathematics classes by sex during 1975-76. Unpublished manuscript, University of Wisconsin-Madison, 1977.

Leviton, H. The implications of the relationship between self-concept and academic achievement. Child Study Journal, 1975, 5, 25-36.

Lim, H. Geometry and the space factors. Unpublished paper for the School Mathematics Study Group, Summer, 1963.

Maccoby, E. E., & Jacklin, C. N. Sex differences in intellectual functioning. Assessment in a pluralistic society: Proceedings of the 1972 Invitational Conference on Testing Problems. Princeton, New Jersey: Educational Testing Service, 1973.

Maccoby, E. E., & Jacklin, C. N. The psychology of sex differences. Stanford: Stanford University Press, 1974.

Meserve, B. E. Geometry as a gateway to mathematics. In A. G. Howson (Ed.), Developments in mathematical education. Cambridge: University Press, 1973.

Minuchin, P. P. Sex-role concepts and sex typing in childhood as a function of school and home environments. In G. C. Thompson (Ed.), Social development and personality. New York: John Wiley & Sons Inc., 1971.

Mullis, I. V. S. Educational achievement and sex discrimination. Denver, Colorado: National Assessment of Educational Progress, 1975.

O'Brien, C. W. Pupil achievement, attendance, and attitudes, and the relationship between teacher perception, teacher sex, and pupil sex (Doctoral dissertation, University of Michigan, 1975). Dissertation Abstracts International, 1975, 36A, 1222.

Primavera, L. H., Simon, W. E., & Primavera, A. M. The relationship between self-esteem and academic achievement: An investigation of sex differences. Psychology in the Schools, 1974, 11, 213-216.

Rowell, J. A. Sex differences in achievement in science and the expectations of teachers. The Australian Journal of Education, 1971, 15, 16-29.

Schonborn, B. G. An investigation of the attitudes of elementary school teachers toward sex-role behavior of elementary school children. Unpublished doctoral dissertation, University of Illinois, 1975.

Sears, P. S., & Feldman, D. H. Teacher interactions with boys and girls. National Elementary Principal, 1966, 46(2), 45-48.

Sherman, J., & Fennema, E. The study of mathematics among high school girls and boys: Related factors. American Educational Research Journal, 1977, 14(2), 159-168.

Shinedling, M., & Pederson, D. M. Effects of sex of teacher and student on children's gain in quantitative and verbal performance. The Journal of Psychology, 1970, 76, 79-84.

Smith, I. M. Spatial ability. San Diego: Knapp, 1964.

Stein, A. H. The effects of sex role standards for achievement and sex role preference on three determinants of achievement motivation. Developmental Psychology, 1971, 4, 219-231.

Stein, A. H., & Smithells, J. Age and sex differences in children's sex role standards about achievement. Developmental Psychology, 1969, 1, 252-259.

Suydam, M. N., & Riedesel, C. A. Interpretive study of research and development in elementary school mathematics, Vol. I. Introduction and summary: What research says. Final report, Project No. 8-0586, Department of Health, Education and Welfare, 1969.

Very, P. S. Differential factor structures in mathematical ability. Genetic Psychology Monographs, 1967, 75, 169-207.

Weaver, J. F. Seductive shibboleths. The Arithmetic Teacher, 1971, 18, 263-264.

Werdelin, I. The geometrical ability and space factor in boys and girls. Lund, Sweden: University of Lund, 1971.

White, R. W. Motivation reconsidered: The concept of motivation. Psychological Review, 1959, 66, 297-333.

Wilson, J. W. Patterns of mathematics achievement in grade 11: Z population. (National Longitudinal Study of Mathematical Abilities, No. 17). Palo Alto, California: Stanford University Press, 1972.

Wirtz, W. (Chairman). On further examination: Report of the Advisory Panel on the Scholastic Aptitude Test score decline. New York: College Entrance Examination Board, 1977.