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1. Title of symposium: Gender differences in participation in mathematics:  
Developmental origins and consequences.

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## Gender differences in participation in mathematics: Developmental origins and consequences

One of the salient features of the American labor force is that relatively few women occupy positions which involve higher mathematics. Differences in mathematical ability between males and females begin to appear at the junior high school level. Achievement test scores for females become increasingly depressed in relation to males' scores. Simultaneously, girls enroll in a smaller number of optional mathematics courses. These two trends reflecting lowered female ability and interest have the broad consequences of reducing the number of women who enter mathematics-related fields and other fields requiring some knowledge of advanced math, e.g. fields requiring knowledge of statistics. The papers in this symposium investigate the developmental origins of these two trends and the career consequences female underparticipation in mathematical courses, focussing primarily on attitudinal and self-concept relevant variables. In addition, the socializing role of peers, teachers and parents are assessed. The first paper provides an ~~introduction~~ introductory overview to the general field and a detailed discussion of methodologies used in these studies. The remaining papers present extensive data relevant to the major hypotheses outlined in the first presentation.

Title of Symposium: Gender differences in participation in mathematics:  
Developmental origins and consequences.

Title of Paper: A national assessment of participation and  
performance of women in mathematics.

Author: Jane Armstrong, & Stuart Kahl

Institute: National Assessment of Educational Progress

Slides: Yes

A National Assessment of the Performance and Participation of Women in Mathematics is a two-year project conducted by National Assessment of Educational Progress. The purpose of the study is to identify the most salient factors related to the problem of women's participation in mathematics and to explore the interrelationships among "causal" variables thereby guiding future research and intervention efforts.

The first phase of the project, which began in October of 1977, was a review of the literature to identify the most promising variables to investigate and to locate existing instruments. During the first eight months of the project, a large number of consultants from various disciplines participated in the survey development by refining variable definitions; reviewing, selecting and editing items; and developing new items and item scales. Survey materials were field tested on two separate occasions using samples of approximately nine hundred each time. Eighth and twelfth grade males and females comprised the field test samples. Item analysis and factor analysis of field test data were invaluable in developing the final survey instrument. Items included in the questionnaire fall in the following categories of variables: sex-role stereotyping, career and academic plans, self-concept in mathematics, school experience (especially in mathematics), student background information, influences of significant others (parents, peers, teachers and counselors) and mathematics achievement.

The Research Triangle Institute of Raleigh, North Carolina will administer the questionnaire to thirteen hundred thirteen-year-olds and sixteen hundred high school seniors both males and females this fall. Seniors taking advanced mathematics courses will be oversampled since they represent such a small proportion of the student population and since this group is of particular interest in this study.

### Survey Rationale

The NAEP survey is a pre-paradigmatic approach for identifying potential variables for intervention. This approach can investigate a large number of variables and by doing so identify areas in which small-scale experimental research would be most productive. Unfortunately, this first step toward determining intervention strategies is usually skipped. Many smaller studies have investigated aspects of the problem in question, yet as one might expect the results have been conflicting, though not necessarily inaccurate considering the special aspects of the samples involved. Furthermore, studies addressing a very limited number of possible causal factors constitute "piecemeal" probes into the nature of the problem. They cannot be expected to provide insight into the complex interrelationships of variables which, by now, we are sure exist. Thus, when it comes to the relative importance of different possible causal factors either across or within population subgroups, little is known. This is the kind of information a large survey can provide to make future research more useful and less "hit-or-miss." In addition to providing descriptive data on a large number of variables and identifying the "most promising," still more can be done with survey data to guide future research and intervention. Further analysis of the data can identify plausible hypotheses which merit more detailed study.

In summary, the survey model allows many variables to be explored while the research model allows a few variables to be explored in greater depth. The survey approach is particularly appropriate for a complex problem like that of female participation in mathematics where there are numerous plausible explanations. Furthermore, a national sample is the only way to resolve those conflicting research findings due to eccentric samples; and with the statistical power available from a large number of respondents, a large-scale survey can detect those stable but small influences that smaller studies are too insensitive to catch.

#### Analysis of Survey Results

Descriptive statistics for the variables will be furnished for subgroups based on sex, race, age and SES. Shifts in performance on variables between ages of the same sex will be analyzed in relation to the effect on mathematics participation. Stratifying on mathematics participation (the major dependent variable) will be helpful in identifying important "causal" factors and their relative importance and the relationships among them.

Title of Symposium: Gender differences in participation in mathematics:  
Developmental origins and consequences.

Title of Paper: Sex roles, attitudes, and achievement in mathematics:  
A study of elementary school children and Ph.D.'s.

Author: Sally L. Boswell

Institution: Institute for Research on Social Problems

Slides: No

The purpose of the present study is to determine how attitudes and career goals affect mathematics achievement at different ages. A heavy emphasis is placed on the possible importance of cultural beliefs and values. Many of these beliefs are related to what has been traditionally deemed as appropriate behavior for males and females. These cultural mores and dictums (transmitted in the form of sex-role stereotypes) may well have the effect of directing girls away from mathematical pursuits. However, the specific processes and ages at which this occurs are not yet well understood. The major objectives of the current investigation are: 1) to determine the ages at which specific attitudes begin to affect females' achievement in mathematics, and 2) to document the specific effects that parents, peers, and the educational setting have on females' mathematical behavior. Towards this end, a series of three interrelated studies have been planned. Two of these studies have been conducted and are described below.

The first study focuses on the identification of the earliest precursors of interest in mathematics. Although achievement tests of mathematical ability do not show significant differences in the scores of males and females until the level of junior high school, the attitudinal patterns which contribute to these achievement differences may well be formed at the elementary school level. Thus, the mathematical attitudes, aptitude and achievement of males and females in grades 3 through 6 are the focus for this first study. A sample of 565 children was obtained from two schools in the Boulder Valley School District. Both of these schools are attended by children ranking above the national average in intelligence and socio-economic status. The attitude items were collected by means of a questionnaire administered to the children in small groups at the school.

One of the central hypotheses of the study is that mathematics is perceived as a field in the male domain and thus an inappropriate field of study for females. It may be the case, however, that girls who exhibit sex-role flexibility will exhibit more positive attitudes toward mathematics. The questionnaire, therefore, included an assessment of sex-role flexibility. The measure employed was a Toys and Activities Test on which the children exhibited their preferences for a list of traditionally masculine and feminine toys and activities. Flexibility scores are derived by calculating the ratio of masculine to feminine preferences.

In addition to sex role flexibility, the questionnaire included items assessing 1) locus of control, 2) achievement motivation, 3) independence, and 4) need for social affiliation. The items selected to assess children's attitudes and beliefs related to mathematics included, for example, liking of math, degree of interest in math, perceived importance of math, and whether mathematics is viewed as belonging in the male domain. Items were also included which assessed children's perception of their parents', teachers', and peers' attitudes toward mathematics. Thus, the questionnaire was designed to determine both general personality factors and attitudes specific towards mathematics to predict mathematical performance, and to identify the interpersonal sources of relevant attitudes. The children's achievement and aptitude scores in mathematics were provided by the Boulder Valley School District.

Preliminary results of the data indicate that sex differences in attitudes related to mathematics appear as early as the third grade. The children of both sexes consider mathematics to be a "male" subject. In keeping with previous literature, sex differences also appear on several general personality characteristics, most strikingly in the locus of control and independence measures. Statistical analyses (including correlation coefficients, discriminant functions and factor analysis) are currently underway which are designed to determine which specific attitudes best predict achievement at the various grade levels, and to identify the sources (parents, peers and the educational setting) which may be contributing to those attitudes.

The second study addresses itself to the positive factors which underlie career choices in mathematics. Why do some women decide to enter the field of mathematics? Since female mathematicians have managed to overcome the cultural, sociological and psychological barriers which seem to prevent so many other women from entering the field, an analysis of their personality characteristics and developmental histories should reveal specific patterns which are related to the pursuit of a career in mathematics.

The experimental sample included 265 female mathematicians. Names and addresses of these women were obtained from departmental chairpersons from universities throughout the United States and also from the American Mathematical Society. Data from the female mathematicians will be systematically compared with a sample of female Ph.D.'s in English (considered a traditionally feminine field) and psychology (considered a non-sex-linked field).

Multivariate analyses are currently being undertaken on the data to identify those variables which maximally differentiate women in the three areas of study. Preliminary analyses indicate that mathematicians perceive a large number of negative stereotypes associated with their field. The vast majority indicated that they believe society views them as masculine, unattractive, cold, distant and peculiar. This finding supports the contention of the paper that negative stereotyping must be considered as a potential source of conflict for young women deciding among career choices. Further analyses are being undertaken to determine the age at which the respondents became aware of these stereotypes and the cultural sources which conveyed this detrimental information.



Title of Symposium: Gender differences in participation in mathematics:  
Developmental origins and consequences.

Title of Paper: The role of attitudes and achievement in the  
development of sex differences in rates of participation  
in mathematics.

Author: Lorelei Brush

Institution: Abt Associates, Inc.

Slides: No

To isolate the causes of women's avoidance of mathematics and to trace the development of their decision for non-participation, this longisectinal study has followed about 1500 students initially enrolled in the sixth, ninth, and twelfth grades. All students were drawn from three New England school systems (one rural, one suburban, one urban). Cohort I consists of about 900 students on whom data were first gathered in 1976-77. A full three years of data will be collected on their attitudes toward, achievement, and course plans in mathematics through the use of a questionnaire administered once a year and follow-up interviews of those students whose interest in mathematics changes most drastically over a year period. Cohort II consists of the remaining children at Cohort I's grade level in the three school systems. Data collection on this group of about 700 children began in 1977-78 when they were given the same questionnaire as Cohort I. In 1978-79, Cohort II will be tested in an identical manner to Cohort I.

Nine areas have been defined as possible predictors of participation in mathematics and are examined in the study; quantitative ability; spatial ability; attitudes toward the creativeness, accessibility, and usefulness of mathematics; a stereotype of mathematics as a male domain; mathematics anxiety; influence of significant others on one's participation in mathematics; expectations of future liking of and grades in math courses; and career aspirations. Analyses of the data have involved comparisons of the sexes on each variable, correlations of each variable with the criterion of participation (or plans to participate) in high school mathematics courses, and assessments of the value of several structural equation models in explaining the interrelationships of the variables. This particular presentation will focus on the testing of competing explanatory models.

First, let us summarize the general trends in the data about the development of attitudes and course plans in mathematics and sex differences in these measures. The trends are clear: male and female students alike show a decreasing interest in mathematics with increasing age; female students are significantly less positive in attitudes and less strong in desire to participate extensively in mathematics than males from seventh grade onward. When one examines the correlations between the attitude and achievement variables and course participation, it is evident that more positive attitudes or higher achievement in all nine areas are related to higher levels of course participation. Thus, a set of relevant measures has been used in the study and clear results have emerged for use in the prediction of involvement in mathematics.

The second step is to attempt to pinpoint the model which most effectively connects the predictor variables of attitudes and achievement/ability with course participation, and to evaluate the role of gender in the model. Initially, this was accomplished by testing the roles of all predictor variables through the use of the LISREL-IV program developed by Karl Jöreskog and Dag Sörbom. Three of the measures -- expectations of future liking and future grades and attitudes toward the usefulness of mathematics -- were critical in the prediction of course plans while the other variables had no direct influence on the criterion. Interestingly enough, there were no sex differences in the path coefficients from these variables to course participation implying that males and females alike take more mathematics if they think they will enjoy the courses, get high grades, and if they can see that mathematics will be useful to them in their future life or job.

Where sex differences gained importance was in the next set of model testing. Through a process of model revision, it became clear that the derivation of expectations about liking, grades, and usefulness of mathematics was different for males and females. In particular, mathematics anxiety was a much stronger predictor of these three variables for females than it was for males. Even with ability/achievement measures held constant across the sexes, females rated themselves as more anxious in quantitative situations than males. The other attitude measures played a role in predicting expectations, but the critical variable seemed to be anxiety.

The significance of the model which best fits the data is that sex is not directly implicated as a predictor of course participation in high school mathematics, but rather that gender has a complex role through sex differences in anxiety. Speculations about the cause of these differences immediately implicate the socialization influences of the family, peers, and teachers and will be discussed at some length in the presentation.

Title of Symposium: Gender differences in participation in mathematics:  
Developmental origins and consequences.

Title of Paper: Origins of sex differences in high school mathematics  
achievement and participation.

Author: Lauri Steel, Markita Gulliver, & Laress Wise

Institution: American Institutes for Research

Slides: No

A number of previous studies have found sex differences in mathematics achievement generally beginning around junior high school and increasing over the high school years. The present research study was designed to (1) investigate the antecedents and correlates of sex differences in mathematics achievement and participation rates and (2) assess the extent to which subsequent educational and career options are limited by low mathematics achievement and participation during high school. The proposed paper reports findings from the first phase of this study concerning the timing and potential origin of sex differences in mathematics achievement with particular emphasis on factors that affect participation in elective math courses.

### Design

The study analyzes data from the Project TALENT data base. These data include extensive information on the backgrounds, personal traits, interests, abilities, activities and plans of a nationally representative sample of about 400,000 students who were in high school (grades 9-12) in 1960, as well as data on the subsequent educational, career, and personal experiences collected over the ensuing 15 years. Phase I of the study is based primarily on a sample of roughly 7500 of the students who were in the 9th grade when originally tested, and who were subsequently retested as 12th graders in 1963.

The analyses used the data from the 1960 student characteristics, from the school characteristics and from the 1963 retest student characteristics. The original Project TALENT testing in 1960 included a 2-day battery of cognitive ability and aptitude tests, interest and personal trait measures, and a 394 item questionnaire covering the students' family background, current academic and extracurricular activities, and future plans. These same instruments were used in the retest of Class of 1963 as seniors except that, because it was necessary to shorten the administration time to a single day, each student was given only half of the battery. (Six forms were used, each containing a different mix of instruments so that each instrument was administered to about half of the students.) In addition to the individual student characteristics, school characteristics such as financial, teacher and student body characteristics were collected in 1960.

The study found more precise assessment of the extent of sex differences in mathematics achievement over the high school years. There were very significant sex differences in 12th grade mathematics achievement with males averaging about one-third of a standard deviation higher in means than females. There were only very slight sex differences in mathematics achievement in the 9th grade. Figure 1 illustrates these differences. The study also provided an assessment of the relative importance of factors contributing to the observed

differences in mathematics achievement. Virtually all of the increases in sex differences during the high school years could be attributed to the sex differences in the math participation rates. Figure 1 also illustrates that the sex differences in mathematics achievement show the sharpest increase after 10th grade when mathematics courses become elective. Interest in mathematics-related careers accounted for the small residual sex differences in achievement gains after initial achievement and the math participation rates were controlled.

The mathematics participation rate was highly related to 9th grade achievement scores, but sex differences in mathematics participation could not be explained in terms of 9th grade mathematics achievement since the 9th grade scores of females matched the males' scores quite closely. The level of educational attainment expected in 9th grade was the next variable most closely related to mathematics participation rates, but here, too, sex differences were too small to explain the differences in math participation. Interest in mathematics-related careers relative to other careers, and interest in mathematics itself were the best predictors of mathematics participation after controlling for 9th grade mathematics achievement and educational expectations. The substantial sex differences in these interests already evident by the 9th grade were sufficient to explain virtually all of the sex differences in math participation.

### Conclusions

Sex differences in mathematics achievement became evident during the high school years and can be largely attributed to differences in mathematics participation, but the origins of these differences can be traced to differences in career interests and attitudes toward mathematics that are already evident in the 9th grade. While programs can be designed to reverse the effect of the sex differences in mathematics achievement and participation in high school, a more appropriate long term solution would be to focus on career education prior to 9th grade and, in particular, on removing sex-stereotyping regarding mathematics and careers.

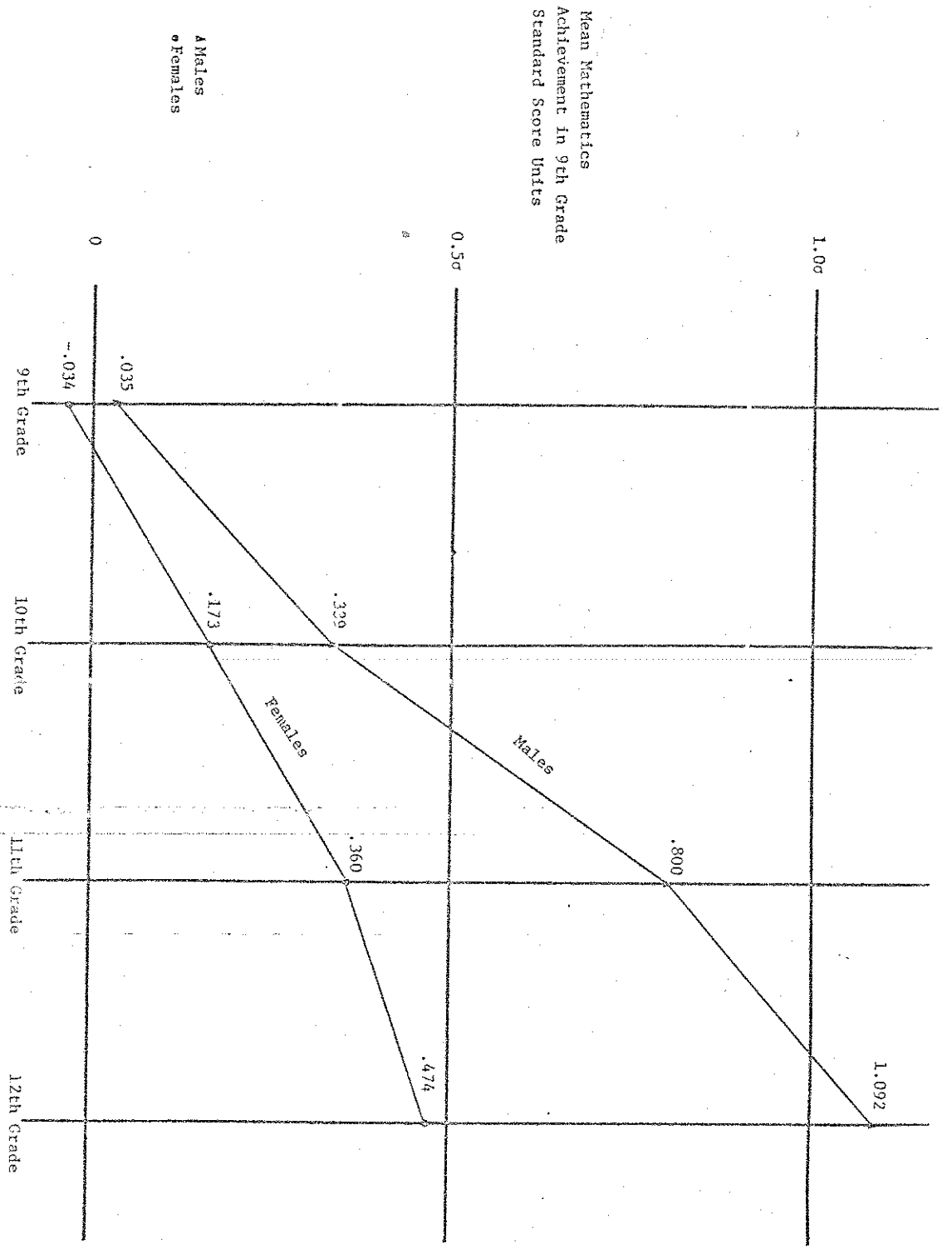


Figure 1. Comparison of Mathematics Achievement Gains of Males and Females