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ABSTRACT

Reported are results of a study comparing the incidence and characteristics of male and female mathematically gifted junior high students, and suggested are ways to encourage female participation in science and mathematics. It is explained that the Study for Mathematically Precocious Youth identified significantly more males than females with outstanding mathematical reasoning ability and also noted differing attitudes (such as greater social values and less inclination to seek out mathematical experiences) on the part of highly gifted girls. An accelerated class for girls only is reported to have been moderately effective in promoting mathematical achievement among girls. It is concluded that the observed sex differences may be biologically based or due to such environmental variables as less parental encouragement for mathematically gifted girls. (DB)

Mathematically Precocious: Male or Female?

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Mathematically Precocious: Male or Female?

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A popular phrase heard at meetings of persons interested in career education, particularly for girls, is "be anything you want to be". One thing very few girls seem to want to be is mathematically talented, or at least employed in professional careers in mathematics and science. Yet boys and girls do not appear to differ with respect to reported liking for mathematics as a school subject in the elementary and secondary school years (Ernest, 1975). When mathematics courses become optional in high school and college, however, far fewer females than males elect to take them (Haven, 1970; Ernest, 1975). The difference becomes greatest at the doctoral level. In 1968-69 only 3.4 percent of the degrees earned in the physical sciences (including mathematics and engineering) were awarded to women (Centra, 1974). It is interesting that girls should report liking mathematics as much as boys, yet avoid taking the courses when they can.

If we are to understand why there are so few creative women in the sciences, we must first try to understand why so few women pursue educational experiences and professional careers in the scientific fields. Are women less-able in mathematics and science or merely less interested?

An ongoing study of mathematical precocity at the Johns Hopkins University offers some interesting insight into the question of sex differences in mathematical precocity. First it provides information concerning the existence of precocious mathematical reasoning ability among adolescents, and secondly it explores the question of how precocious achievement in mathematics can be fostered.

The Search for Mathematically Gifted Adolescents

The Study of Mathematically Precocious Youth (SMPY) began in the fall of 1971 to search for junior-high-school-age students who were precocious in mathematical reasoning ability as evidenced by very high scores (660-800) on the Scholastic Aptitude Test Mathematics (SAT-M). In order to discover these talented students, SMPY conducted a talent search in each of the years 1972, 1973, and 1974 (Stanley, Keating, Fox, 1974).

The 1972 Contest

In March of 1972 seventh, eighth and young-in-grade ninth grade students in the greater Baltimore area who had scored at or above the 95th percentile on the numerical subtest of an in-grade standardized achievement test such as the Iowa Tests of Basic Skills were invited to participate in a contest. Three hundred ninety-six students (223 boys and 173 girls) accepted the challenge and took the SAT-M.

The results of the testing were startling. Twenty-two boys (about 10 percent of the male contestants) scored 660-790 on the SAT-M. This is better than the average Hopkins student scored as an eleventh or twelfth grader. Clearly, there are many mathematically precocious boys. The highest score for a girl, however, was 600. Although 44 percent of the contestants were girls, 19 percent of the boys scored higher than the highest scoring girl. The difference in points between the highest scoring boy and the girl was 190 points (Stanley, 1973; Keating, 1974).

The 1973 Contest

In the winter of 1973 a second talent search was conducted. This time students were considered eligible for the contest if they had scored at or above the 98th percentile on an in-grade numerical subtest of a standardized test such as the Iowa Test of Basic Skills. Wider publicity helped to increase the total number of students who participated. There were 666 students in the contest (420 boys and 246 girls). The percentage of girls, however, dropped from almost a half (44 percent) in 1972 to just over a third (37 percent) in 1973. This decrease in participation by girls may have been due in part to the fact that there were actually two contests in 1973 - one for mathematics in January and one in the verbal area in February. Students in both contests took the SAT-M and SAT-V. Students were told they could enroll for either contest and be eligible for prizes in both. The total number of students in both contests was 953. There were 537 boys (56 percent) and 416 girls (44 percent).

The highest SAT-M score for a girl in the 1973 contests was 650, while two boys (one a seventh grader) attained scores of 800 (Stanley, 1973). Seven percent of the boys in the 1973 contests scored 660 or more. No girl did.

The 1974 Contest

In January of 1974 a third talent search for mathematics was held. Students throughout the entire State of Maryland who had scored at or above the 98th percentile on the numerical subtest of a standardized achievement test were eligible for the contest. The testing was conducted in four centers across the state. A total of 1519 students took the SAT-M. Thirty-nine percent of the participants were girls (591).

Sixty-one students scored 660 or above. Seven of those students were girls. One girl scored 700. The highest score earned by a boy was 760. In 1974 less than 2 percent of the boys scored higher than the highest scoring girl.

Sex Differences

Thus as early as grades seven and eight boys out-perform girls on difficult pre-college level tests of mathematical reasoning ability and the differences are particularly striking at the upper ends of the distributions. The distribution of scores by sex are shown in Table 1.

Insert Table 1

The mean scores by sex and grade are shown in Table 2.

Insert Table 2

In three years of searching SMPY has identified considerably more males than females who are highly precocious mathematical reasoners. The self-selection aspect of a contest may have contributed to the greater male than female participation in the contest but this does not explain why the ratio of boys to girls who scored 660 or above (16 to 1) was so much greater than the overall ratio of boys to girls in the contests (1.4 to 1).

Whether or not these apparent differences in mathematical aptitude for the two sexes is a result of biological differences or differential cultural reinforcements over time, or a combination of the two, is not clear. One would expect to find a large gap at the upper end of the distribution of mathematical ability (as was found by SMPY) if the biological explanation of sex differences in mathematical ability is correct.

At the present time, however, many researchers feel that there is too little known about the inheritance of specific abilities such as mathematical aptitude to justify such a conclusion (Maccoby and Jacklin, 1975; Astin, 1974).

Some researchers believe that the differences between the sexes in average performance on tests of specific abilities such as mathematics reflect differential cultural reinforcements over time which have shaped the career and educational goals, interests and achievements of the two sexes (Aiken, 1970; Astin, 1968a, 1968b, 1971; Hilton and Berglund, 1971). SMPY's study of the characteristics of mathematically precocious adolescents does lend some support for the social explanation of sex differences at the higher levels of ability and achievement.

Boys who scored 660 or more on SAT-M had stronger orientations towards investigative careers in mathematics and science and greater theoretical value orientations than did their less mathematically precocious male and female peers on the Allport-Vernon-Lindzey Study of Values (Fox and Denham, 1974; Fox, 1976). Many of the highly mathematically precocious boys report studying mathematics and sometimes science textbooks systematically with the help of a parent or interested teacher, while others have worked informally with mathematical puzzles, games and books. What has motivated this extracurricular pursuit of knowledge appears to be strong theoretical and investigative values and interests.

Girls, even the most mathematically talented, are far less likely than boys, particularly the most mathematically talented boys, to seek out special experiences related to mathematics and science. Girls tend to have values and interests of a more social than theoretical nature (Fox and Denham, 1974; Fox, 1976). Thus it is not surprising that few girls report that they study mathematics on their own. Thus differential performance by the sexes on difficult pre-college level tests of mathematical reasoning ability at grades seven and eight could be partially a result of differential exposure to and practice with mathematical problem solving situations which result from different interests and value orientations.

Girls also appear to receive less encouragement at home to consider scientific pursuits. In a small sample of gifted students studied by Astin (1974) parents of boys often had noticed their sons' interest in science at an early age. Parents of boys typically reported that they had discussed college careers in science, mathematics, medicine, and engineering with their sons. These parents reported providing more scientific materials such as toys, books, and games for their sons than did parents of girls. Very few parents of girls had noticed their daughters' showing interest in mathematics or science at an early age. The occupations which these parents had discussed with their daughters were more apt to be traditionally feminine ones such as nursing and teaching. The parents of the girls had given less thought to future educational plans for their daughters than had the parents of boys.

Haven (1972) found that girls who take advanced mathematics courses are those who receive encouragement from parents, guidance counselors, mathematics teachers, and peers. Thus, having the support of significant others is necessary to encourage girls who have somewhat deviant (i.e. rare or masculine) career interests.

Studies of women who have received the doctorate (Astin, 1969) and of creative women mathematicians (Helson, 1971), indicate that identification with professional fathers, encouragement from appropriate female role-models, and parental support were important factors in the development of these women. Many successful women mathematicians are first generation Americans, or daughters of first generation Americans. Many are also oldest daughters in all-girl families. It has been hypothesized that families which have no sons and immigrant families are more likely than other types of families in the United States to encourage their daughters' educational and career aspirations.

Whether or not gifted girls receive much special encouragement at home to aspire toward professional careers, they are not likely to get much special career counseling in school or special encouragement in mathematics classes. Teachers believe that boys are better at mathematics than girls (Ernest, 1975) and thus probably fail to notice and encourage those girls who do have real aptitude for mathematics. Even in these supposedly "liberated times", gifted girls who attempt to accelerate their mathematics education may be ridiculed or discouraged by insensitive teachers or peers. Clearly, many girls anticipate rejection for appearing different by moving ahead in mathematics (Fox, 1974a, 1974b; 1975).

Fostering Precocious Achievement

Although it is difficult to draw conclusions about the relative influences of biological and social factors upon the performance on measures of aptitude (e.g. some would even argue the possibility that some of the differences in test performance are artifacts of biased test materials), there is clear evidence that precocious achievement in mathematics can be directly influenced by environmental factors. SMPY's attempts to foster acceleration in mathematics provide some interesting insight into the dynamics of precocious achievement among bright adolescent boys and girls.

Accelerated Classes

In the summer of 1972, 30 end-of-the-year sixth graders (18 boys and 12 girls) were invited to a special summer mathematics class which met two hours a week. Fourteen boys (78 percent) and seven girls (58 percent) enrolled for the program. The initial success of the class in mastering Algebra I with only 18 hours of instruction was so great that the class continued to meet for two hours a week through the middle of the following summer. Of the 21 students who initially began the course, six boys (43 percent) and one girl (14 percent) completed the study of all their pre-calculus mathematics (Algebra I, Algebra II, Algebra III, Plane Geometry, Trigonometry and Analytic Geometry). Six of the boys took calculus the following year in a senior high school.

In the summer of 1973, 85 students (51 boys and 34 girls) who had participated in the 1973 talent search and who had scored at least 500 on SAT-M and 400 on SAT-V were invited to a summer accelerated mathematics class. Most of these students were eighth graders who had completed Algebra I. Twenty-two boys (43 percent) and nine girls (29 percent) enrolled. Fourteen boys (64 percent) and none of the girls completed all the pre-calculus mathematics by the middle of the following summer meeting only two hours a week during the school year and four hours a week during the second summer. (George and Denham, 1976).

Although these classes were highly successful in promoting precocious achievement in mathematics among boys, they were both far less successful with girls. First, more boys than girls were eager to enroll in such a program. Secondly, girls who did enroll tended to drop out of the classes before their completion.

Interviews with the girls indicated that one major reason for dropping out was a reluctance to become accelerated in their placement in school.

Many of the girls seemed to fear being labeled as different from their friends by virtue of becoming somewhat accelerated. Girls also reported that the class meetings were dull, and some made references to the boys in the classes as "little creeps". The overall reaction to the classes by the girls was that it was socially unappealing and might have negative social consequences for the girls in school.

It has been reported that even very bright girls often self-select themselves out of advanced mathematics classes in high school (Haven, 1972) and that few women ever pursue doctoral degrees in mathematics (e.g. in 1969 only seven percent of the doctoral degrees awarded in mathematics were earned by women (Bisconti and Astin, 1973)). Until this present study, however, it was not known that bright girls in junior high school would be far more reluctant than boys to partioipate in special accelerated mathematics programs and, especially to persist in them.

A Class for Girls Only

The results of testing values and interests of boys and girls in the 1973 contest suggested that even the most mathematically able girls were likely to prefer social to theoretical activities. In combination with the results of the first two accelerated mathematics classes this suggested that to interest girls in learning mathematics faster it would be important to consider the social aspects of a program.

Thus in the Spring of 1973 an all-girls accelerated Algebra I class was organized for seventh grade girls who had been in the 1973 contest and who had scored at least 370 on SAT-M (the average of female juniors in high school). The details of the program for girls are reported elsewhere (Fox, 1974b). In brief, the class was designed to appeal to the social interests of girls in a number of ways. It emphasized social cooperation rather than competition and was taught by a woman rather than a man. Men and women scientists and mathematicians spoke to the girls about exciting careers in mathematics and science (such as operations research, health statistics, and social science research) which deal with social problems as well as theoretical ones. This approach to an accelerated program was considerably more effective in recruiting girls. Of the 34 girls invited, 26 enrolled (76 percent). Eighteen girls (69 percent) completed the course. Not all girls, however, chose to accelerate their mathematics in school the following year and a few actually met with resistance from their schools to their acceleration. Eleven did take Algebra II the following year; 10 of these (38 percent) were considered to have been successfully accelerated. The girls are now in the tenth grade and 12 of them are at least one year accelerated in mathematics.

The emphasis on the social interests of girls was moderately effective in promoting greater achievement in mathematics for girls than had the two mixed-sex more theoretically taught classes. This approach, however, did not promote the same extent of acceleration for the girls that the other two programs did for the boys.

Other Alternatives

SMPY and the Intellectually Gifted Child Study Group have also found that gifted adolescent girls are less eager than their male cohorts to skip grades in school or take college courses in subjects like computer science and mathematics. Girls are also less likely than boys to take advanced placement courses in science and mathematics in high school The reason girls avoid these experiences seems to be a result of fear of failure and fear of social rejection by peers.

Conclusions

On the basis of SMPY's research on the mathematically precocious, it appears that males are more likely than females to perform at a very high level on pre-college level tests of mathematical reasoning ability (at least in a voluntary contest situation). The sizable gap between the sexes on mean SAT-M scores and at the upper end of the distribution as early as grade seven suggests that there may be biologically-based differences between the sexes with respect to mathematical aptitude. There are, however, strong indications that some of the apparent differences are related to environmental factors. Whether or not greater efforts to encourage and develop mathematical interests among women in childhood and adolescence could eliminate or reduce this sex difference at the higher levels of ability is not known.

Clearly it is much more difficult to foster precocious achievement and acceleration in mathematics among girls than boys. Some attention to the social interests of young women in structuring learning environments to foster accelerated achievement appears to increase the rate of participation and success of females. To date, however, SMPY has not effectively helped to accelerate any girl as far or as fast as most of the boys in its programs. This should not be interpreted as meaning that it is unprofitable to work with bright girls. Although mathematical precocity (both in measured ability and achievement) is far more evident among young males than females, SMPY's efforts to foster greater achievement among very bright students does suggest that girls can be helped to develop their quantitative potentials more fully.

If society is truly committed to encouraging women to develop all their talents more fully, how can this be done? Removing external barriers, such as sex discrimination in hiring, will not automatically cause women to surge forth to fill the ranks of scientists.

If we desire to increase women's participation in the world of science and mathematics at a professional level, special efforts will be needed to encourage women to think seriously about these career areas. Since the decline in both mathematical interest and achievement appears to occur at about the time girls begin secondary school, programs aimed at increasing women's participation in careers should probably begin early, even as early as the elementary school years. Efforts directed only at the young girls are likely to be less successful than programs which aim to change attitudes of parents and educators as well.

Since most girls value social interests and careers of a social service nature, attempts to teach girls about the ways in which mathematics and science can be used to solve social problems would seem desirable. Thus, it might be appropriate to initiate courses in applied mathematics at the junior and senior-high school levels. Statistics and computer science both have great appeal to young girls and boys. Courses in environmental problems, psychology, oceanography, medical science, operations research, health statistics, and so forth, could be offered, perhaps as mini-courses, to stimulate interest in the applications of mathematics and science to real world problems. The teaching of such courses might be greatly enhanced by visits with scientists in their laboratories.

Teachers of mathematics and science at all levels should examine their own classroom behaviors to see how they can foster greater interest in mathematics among girls. Teachers should also examine their textbooks for sexism, as well as their own casual remarks in class. They might make an effort to include a unit on the history of mathematics and science which includes mention of the contributions of women, as well as men.

Mathematics and science teachers could join forces with counselors to create special career counseling programs for girls. Girls may need special counseling to help them see how important mathematics and science courses are as background for a wide variety of careers. Women scientists and other professionals might visit the school to talk with girls about their careers. Teachers and counselors might make special efforts to encourage girls and their parents to think about educational and career opportunities in fields such as engineering, statistics, accounting, and so forth.

Mathematics and science are exciting career fields. Women, however, need help in learning that jobs with intellectual and social challenges in science and mathematics exist for them, as well as for men.

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Table 1: Distribution of SAT-M Scores, by Sex, for Students in 3 Maryland Talent Searches conducted by the Study of Mathematically Precocious Youth (SMPY), of The Johns Hopkins University.

	1972		1973		1974	
	Girls	Boys	Girls	Boys	Girls	Boys
710-800	0	7	0	15	0	16
610-700	0	36	14	61	33	128
510-600	46	60	82	196	171	353
410-500	67	70	119	116	284	324
310-400	50	44	29	31	94	99
210-300	10	6	2	2	9	8
N	173	223	246	421	591	928

Table 2: Mean Scores and Standard Deviations, by Sex and Grade, for Students in 3 Maryland Talent Searches conducted by SMPY.

	1972				1973				1974			
	7G	8G	7B	8B	7G	8G	7B	8B	7G	8G	7B	8B
N	77	96	90	133	88	158	135	286	222	369	372	556
$\bar{X}$	423	458	460	528	440	511	495	551	440	503	473	540
S.D.	75	88	104	105	66	63	85	85	68	72	85	82