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ABSTRACT

At puberty differences in ability and interest in mathematics between the sexes appear, and they increase with age. This paper describes a special algebra workshop for gifted seventh-grade girls which was designed to improve their competence and accelerate their progress in mathematics, and to increase their awareness of career opportunities in math-related fields. The effect of participation in this summer program is evaluated in terms of achievement in mathematics and changes in attitudes towards mathematics. A comparison is made with nonaccelerated matched control groups. The implications for understanding mathematical precocity are discussed. (Author)

The Mathematically Precocious: Male or Female?

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The status of women in education and career areas, particularly professional careers, has become an issue of popular concern. There is a growing interest in more fully developing women's potentials for participation in mathematical and scientific occupations. To date few women have achieved great success in these fields. In 1969 only seven percent of the doctoral degrees awarded in mathematics and 16 percent of the doctorates awarded in the physical sciences were earned by women (Bisconti and Astin, 1973). Helson (1971) studied the characteristics of living women mathematicians in the United States who were deemed creative. Of the estimated 300 women who had doctorates in mathematics at that time only 18 were considered highly creative by the ratings of their peers and amount of published work. Thus we must conclude that high level achievement in mathematics among women is rare.

Many have felt that women's failure to seek careers at the higher levels of mathematical and scientific endeavors is due partly to differences between the sexes in competence in these areas. If this is true we should expect to find evidence of differences between the sexes at the higher levels of mathematical ability. Some support for this hypothesis comes from the study of mathematical precocity.

Typically what is known about extreme mathematical talent in youth is gleaned from retrospective study of the lives of eminent persons. Several famous scientists, mathematicians, and quantitatively oriented

philosophers such as Pascal, Leibnitz, and Gauss are reported to have been mathematically precocious children. In the twentieth century Norbert Wiener, Charles Fefferman, Michael Grost, Joseph Bates, and Edith Stern received some attention from the news media for their rapid matriculation through the educational system. Whether or not Fefferman, Grost, Bates, and Stern will become eminent in mathematics or related areas remains to be seen. Certainly Fefferman has made a good start by being appointed a full professor of mathematics at a prestigious university at the age of 22. Clearly in both historic and contemporary accounts of genius and precocity there are far fewer women than men reported (Cox, 1926; Stanley, 1974; Stern, 1971).

Perhaps because of their apparent rarity such cases of precocious intellectual development and educational acceleration have received little attention from educators and psychologists. Although the field of general intellectual giftedness has been researched, not even the monumental work of Terman (1925) provides insight into the development of specific talents or evidence concerning precocious educational acceleration and achievement among gifted children. Thus until very recently there has been little evidence to suggest whether or not extremely precocious development in mathematics is indeed more rare among females or merely less visible.

Since it is known that bright women selectively take fewer mathematics and science courses during the high school and college years than their male counterparts, comparisons of gifted high school, college, or adult populations with respect to mathematical aptitude and achievement are difficult to interpret (Haven, 1972). It is not easy to partial-out all the effects of differential expectations, education,

and experience. The time and place to begin research to determine whether or not mathematical precocity is equally common among the sexes would seem to be during the late elementary and early secondary school years. This would presumably "catch" the children at an age and time before self-selection (at least formal self-selection of subject matter in school) has had a chance to operate. Studying gifted children in the early elementary school years may be less desirable because of their lack of attainment of what Piaget (1966) calls formal operations. The developmental stage of formal operations relates to the development of the ability to think abstractly which is critical to the study of advanced mathematics. Keating (1973) found that most intellectually gifted fifth grade boys have obtained this level of development in the Piagetian stages as had gifted seventh grade boys, whereas few average fifth or seventh grade boys had done so.

A recent study of mathematical precocity at The Johns Hopkins University is unique in the fact that it provides us with information about the existence of extreme mathematical talent in adolescents as well as some insight into how precocious achievement in mathematics can be fostered. The preliminary results of the Study of Mathematically and Scientifically Precocious Youth (SMSPY) provides some evidence as to the extent and nature of sex differences in mathematical talent (Stanley, Keating, and Fox, 1974).

SMSPY began its search for adolescent talent in the fall of 1971. It soon became apparent that the most efficient way to identify the mathematically precocious would be by testing large numbers of gifted students on difficult college level tests. In the spring of 1972 396 students from the Greater Baltimore area who scored at or above the

95th percentile on the Iowa tests came to the Hopkins campus to take the SAT-M and CEEB Math Achievement I. This large scale testing was productive. Twenty-two boys or 10 percent of the male contestants scored at or above 660 on the SAT-M, which is better than the average Hopkins student scored as an eleventh or twelfth grader. Further testing of these young students revealed that they had excellent nonverbal reasoning ability as measured by the Advanced Raven's Progressive Matrices as well as good verbal reasoning ability as measured by the SAT-V. Nor were these youngsters socially inept or immature. Many had wide ranges of interests and talents.

Although 44 percent of the contestants were girls, no girl scored above 600 on the SAT-M. Nineteen percent of the boys scored higher than the highest scoring girl. This difference was startling.

In the winter of 1973 a second talent search was conducted. Although wider publicity helped to increase the number of students who participated in the contest, and to reduce the gap between the sexes, it did not obliterate the differences. While only seven percent of the male contestants surpassed the highest scoring girl, the difference in scores between the best boys and best girls was still quite large. The highest score for a girl was 650, while two boys (one a seventh grader) attained scores of 800 (Stanley, 1973).

Although the gap between the sexes was smaller in 1973 than in 1972 the fact remains that extreme precocity (scores above 660) is virtually absent among the girls. While girls may be as bright as boys and perform as well or better in school classes, there was a definite difference between the sexes in performance on difficult college level tests of mathematics. An examination of the characteristics of highly

precocious boys suggests some reasons for this difference.

Many of the highly precocious boys (scoring 660 or more) in the 1972 and 1973 talent searches had learned considerable mathematics through independent study--sometimes under the guidance of a parent or teacher. In some instances the boys reported having simply gained knowledge of advanced mathematics as a result of their own exploration of books, mathematical puzzles, and games. It appears that few girls are encouraged to accelerate their mathematics education. Nor do many girls seek mathematical stimulation from books, games, or puzzles.

What motivates some bright boys to seek out this extra stimulation in science and mathematics seems closely related to their values and interests. Mathematically precocious boys tend to have strong orientations toward careers in mathematics and science (Fox and Denham, 1974). The highly precocious boys scored very high on the theoretical scale of the Allport-Vernon-Lindzey Study of Values. For most of the precocious boys the theoretical value is the highest. It is rare to find a precocious boy who scores highest on the social scale or the aesthetic scale (Fox, 1973).

Thus highly precocious boys seem to have interests and values which are investigative and theoretical and which are highly compatible with the pursuit of scientific fact and theory. It is interesting to note that creative men mathematicians are reported to score high on both theoretical and aesthetic scales of the AVL Study of Values (Mackinnon, 1962). Perhaps some of the precocious boys will develop more aesthetic interests as they grow older. (Aesthetic values are reported to increase for college students [Feldman and Newcomb, 1969].)

Although many of the girls in the talent searches expressed inter-

est in careers in science or mathematics, they were much more interested in careers of an artistic or social nature than were boys (Fox and Denham, 1974). Girls who scored high on the SAT-M were more likely to be interested in scientific careers than girls who scored low. Very few girls scored high on the theoretical scale of the AVL Study of Values (Fox, 1973). Girls typically scored highest on the social or aesthetic scales. Thus it seems reasonable to conclude that most bright girls are not motivated by their interests and values to seek scientific and mathematical pursuits in their leisure time. Other researchers have noted the relationship of career interests (Astin, 1968a, 1968b, 1971) and sex-typed interests to differences in mathematical ability (Hilton and Berglund, 1971).

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. They typically reported that they had discussed college careers in science, mathematics, medicine, and engineering with their sons. They 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.

Not only do girls fail to seek out stimulation in science and mathematics on their own, but also they appear to be far less interested

than boys in taking advantage of special educational opportunities which are offered to them in these areas. A major focus of SMSPY has been to offer free educational counseling to the highly precocious (Fox, 1974). The highest scoring boys have been eager and anxious to try new things and openly expressed boredom in their regular school situations, but the reactions of the best girls to these suggestions and opportunities has been noticeably different from that of the best boys. Girls are reluctant to try skipping a grade, taking a college course such as computer science, or enrolling in special accelerated mathematics programs, and are less critical of school. The reason seems to be that girls are afraid to try things which might make them appear different in relation to their peers (Fox, 1974).

By the fall of 1973 32 students in the program had taken college courses for credit. They typically earned A's and B's and reported enjoying the courses very much. Although several girls were offered the opportunity, only two girls have taken college courses.

As a result of the educational intervention efforts of SMSPY a large number of boys have accelerated their progress through school and have entered or will enter college two to four years early (Keating and Stanley, 1972; Stanley, 1973). Many of these boys will major in mathematical or scientific areas. At present only one girl is known to be accelerating by as much as two years. She will enter a pre-med program next fall.

SMSPY has found that for very bright students encouragement plus opportunity to study mathematics at a high level and at a very fast pace can lead to some extraordinary results. In one special program eight students completed more than four years of mathematics study in

thirteen months meeting only two hours a week on Saturday mornings. Only one of the eight was a girl. Six other girls and two boys in the special class finished somewhat less material. All of these eight completed at least Algebra I and II in that time. These students had just completed the sixth grade when they began their studies. It is apparently feasible to accelerate the study of mathematics quite effectively in a short period of time (Fox, 1974b). However, the differential success rates between the two sexes in this program suggested that the necessary ingredients of encouragement and opportunity need to be operationally defined in somewhat different ways for boys and girls. Details of such special experimental educational intervention programs (including one designed specifically for girls) will be discussed at another paper session on Friday entitled Sex Differences in Mathematical Talent: Bridging the Gap (Fox, 1974c).

In brief, let us note that among very bright students precocious mathematical talent can be fostered. Within this restricted group of high ability youngsters measures of interest, personality, and home background variables seem to account for the differential success of the students in special programs designed to challenge them and accelerate their educational progress. The effects of family background variables and personality upon academic success of women has been reported by Astin in her Study of the Woman Doctorate in America (1969) and by Helson (1971) in her Study of Creative Women Mathematicians. The creative women mathematicians were typically from all girl families and many were first generation Americans or foreign born. It is interesting to note that the girl who completed the most mathematics in the first special program at Hopkins is a first generation American and in

an all girl family.

On the basis of the analysis of the first two talent searches by SMSPY and the experimentation with fostering mathematical achievement we must conclude that extreme mathematical ability does abound, but it is more rare among gifted females than among gifted males. This would lend some support to the contention that men have surpassed women in the number of their contributions to mathematical and scientific endeavors at least in part because more men have more talent. However, happily the source of data on mathematical precocity does not end with the search for talent in 1973.

In the winter of 1974 a third talent search was held. One thousand five hundred and sixteen students from all over the State of Maryland entered the contest. Sixty-one students scored 660 or above. Seven of those students were girls. In fact, one girl scored 700. Thus in the 1974 competition less than two percent of the boys scored above the top girl and the gap between the highest scoring girl and boy was only 60 points. Perhaps a talent search in 1975 would find even smaller differences. (At present there are no plans for a state wide search in 1975.)

Of course it still appears that there are many more highly talented boys than girls but the evidence of greater female talent in 1974 is an encouraging sign. What factors can account for the differences between the results of three years of testing? Two possible partial explanations come to mind. One is that increased publicity may have led more girls to enter the contest. Many schools and school systems conducted their own preliminary talent searches to select contestants for the state wide contest. Secondly, SMSPY has been experimenting with some

special educational intervention programs to encourage acceleration in mathematics for gifted students. Three of the seven girls who scored over 650 had been accelerated by at least one year in mathematics as a result of SMSPY's efforts. The top scoring girl (700) had been accelerated by almost four years in mathematics. Although she is only an eighth grader she had completed the study of Algebra I, Algebra II, Algebra III, plane and analytical geometry, and trigonometry in the first special mathematics class conducted at Hopkins. She is the first generation American girl in the all girl family mentioned earlier.

All in all the data on mathematical precocity and the sexes is far more suggestive than conclusive. In the light of the history of women's roles in society a true evaluation of women's potentials for participation in creative scientific endeavors cannot realistically be based on evidence from centuries past. The fact that there are few known women who were mathematically precocious does not preclude the possibility that there will be precocious women in the future. The preliminary results of SMSPY suggest that if in the future we wish to find more mathematically precocious women we may have to do some serious retooling of our present educational strategies for the gifted child. Certainly there are many avenues for future research.

Biology may be destiny, but humans have never been fainthearted in challenging the "laws of nature." Although we cannot conclude that sex differences in mathematical talent do not exist or that they can be miraculously erased by educational intervention or widespread social reforms, we should conclude that mathematical precocity, male or female, is still an open question.

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