SMPY'S FIRST DECADE: TEN YEARS OF POSING PROBLEMS AND SOLVING THEM

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The Study of Mathematically Precocious Youth (SMPY) began in 1971 with the purpose of devising ways of identifying and facilitating the education of such students. The solutions and their longitudinal evaluation are described. Use of the Scholastic Aptitude Test (SAT) was shown to be an effective way of identifying students in the 7th grade who would achieve academically at a superior level in high school. Moreover, acceleration was deemed an effective alternative for educating gifted children. Curricular flexibility rather than special programs for the gifted has proved the most effective way to facilitate the education of precocious students. For the mathematically precocious, SMPY devised fast-paced mathematics classes. These were shown to have long-term effects. SMPY has also discovered large sex differences in mathematical reasoning ability and in mathematics and science achievements in high school.

During the summer of 1968 Doris K. Lidtke, then an instructor in computer science at the Johns Hopkins University, brought to the attention of Dr. Julian C. Stanley, a 12-year-old boy just out of the seventh grade who was doing remarkable things in the computer laboratory. When in January 1969 Dr. Stanley tested him, he found this boy's performance on several college-level tests of mathematical, spatial, mechanical, and verbal aptitude so remarkable that he asked the boy to take the College Board's Scholastic Aptitude Test (SAT), Physics achievement test, and Mathematics Level I and the more difficult Level II achievement tests.

His scores were as follows: SAT-Verbal (SAT-V), 590; SAT-Mathematical (SAT-M), 669; Math I, 642; Math II, 772; and Physics, 752. His Math II and Physics scores exceeded those of most regular freshmen at the Johns Hopkins University. His SAT-V score was about 40 points below that of the average Hopkins freshman. Thus it seemed evident that Joe, though less than 13½ years old and in only the eighth grade of a public junior high school, was intellectually equipped to do good work as a freshman at a selective college or university such as Johns Hopkins.

The experiences Dr. Stanley had with this brilliant young man made him wonder if there were other such students. How many might there be? How could he identify them and facilitate their education? What happens to these students later in life? Could he enhance their adult achievements?

With these thoughts in mind Dr. Stanley officially began on September 1, 1971 the Study of Mathematically and Scientifically Precocious Youth (SMSPY) in the Department of Psychology at the Johns Hopkins University. Its beginning was made possible by a generous 5-year grant from the Spencer Foundation of Chicago, which itself was then almost new.

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IDENTIFICATION

Considerable local newspaper publicity that fall brought a number of bright seventh- and eighth-grade boys and girls to be tested, including several of the most talented yet found. To Dr. Stanley and the small SMSPY staff, however, neither the average level of talent nor the numbers seemed adequate. Then, in March 1972, with the aid of Daniel P. Keating and Lynn H. Fox, he launched what proved to be the first of ten talent searches thus far. Having learned from prior experience with Joe and then later with Jonathan Middleton Edwards and Jeffrey Nathan Rottman that the College Board's SAT and high school-level achievement tests are powerful identifiers of mathematically and scientifically brilliant youths, they chose two of these for that first attempt to find such students in the Baltimore vicinity. One was SAT-M, the mathematical part of the SAT. It was already known to measure mainly mathematical reasoning ability, only lightly dependent on specific mathematics knowledge (Angoff, 1971; Messick & Jungeblut, 1981). The other was the Mathematics Level I achievement test of the College Board, a somewhat less advanced measure of knowledge of pre-calculus than is Level II. A total of 396 students took these two tests. The composition of that group by sex and school grade is shown in Table 1. Table 1 also shows the composition of the 192

TABLE 1
MEAN SCORES OF STUDENTS ON THREE MEASURES: SAT-M, M-1, AND SCIENCE[a]

Tests Taken	Test	Statistic	7th grade Female	7th grade Male	8th grade Female	8th grade Male	9th grade Female	9th grade Male	All Examinees
		N	59	67	63	67	–	2	258
Math		Mean	416	450	472	516	–	620	466
Only	SAT-M	S.D.	71	104	76	100	–	42	97
		Mean	393	398	431	451	–	540	420
	M-1	S.D.	46	63	48	76	–	28	65
		N	18	23	32	62	1	2	138
		Mean	448	487	427	531	510	760	492
	SAT-M	S.D.	86	100	104	109	–	42	115
Math		Mean	407	437	414	467	500	695	445
and	M-1	S.D.	58	86	52	86	–	106	84
Science	Science 1A &	Mean	74	83	69	88	100	106	81
	1B	S.D.	13	19	16	21	–	3	20
		N	7	13	4	29	1	–	54
Science	Science	Mean	65	66	69	80	103	–	74
Only	1A & 1B	S.D.	7	13	19	18	–	–	17

Note. From "The Study of Mathematically Precocious Youth" by D. P. Keating, in J. C. Stanley, D. P. Keating, & L. H. Fox (Eds.), *Mathematical Talent: Discovery, Description, and Development.* Baltimore: The Johns Hopkins University Press, 1974, pp. 23-46. (Copyright 1974 by the Johns Hopkins University Press, reprinted by permission.)

[a]The total number of students taking the mathematics test was 396. The total number taking the science test was 192. Both sets of tests were taken by 138 students.

students who entered the science competition and took the Sequential Tests of Educational Progress (STEP II), Science, Level I (college), Forms A and B. Keating (1974, pp. 25-28) described the situation well:

> The first problem then was to find these precocious students in some systematic fashion. Informal methods such as teacher or parent references proved insufficient, so a mathematics and science competition was organized for seventh and eighth graders. There was no official screening beforehand, but a number of would-be contestants dropped out after receiving the SAT practice booklet and working the practice test.[1] The total number of test takers was 450, with 396 taking math, 192 taking science, and 138 taking both.
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> . . . Perhaps the single most important finding of our study thus far, and one which we are inclined to overlook because we have become acclimated to it, is that there is a remarkable number of almost unbelievably able and academically accomplished young students in grades seven and eight. (Accelerated ninth graders were also eligible.) The level of their ability can be inferred from table [1], but the picture becomes even clearer when we look at the highest scorers within this able group. . . . Clearly, whether aptitude *or* achievement tests are used to measure the ability of these students, the best of them are competitive with superior high school seniors. . . .
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> One of the striking and unexpected differences which emerged from this large screening session was the sex difference in mathematical precocity. . . . There were 43 boys with an SAT-M score of 610 or greater, whereas the three highest scoring girls earned 600. . . .[2]
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> . . . [T]he science test was relatively inefficient in screening in the level of talent we are seeking. . . . Thus, we are dropping the science tests in our future large screening sessions. Those who are screened in on the basis of mathematical talent will, of course, be tested subsequently for their knowledge of general science.
>
> Approximately six weeks after the general testing we invited back the high scorers for some additional testing, both cognitive and non-cognitive. These students were those who had ranked the highest on math and/or science.

In this manner, following the publication of the first report volume (Stanley, Keating, & Fox, 1974) only 3 years after SMSPY was started, the project became known by its present SMPY designation. In retrospect, this was wise further specialization; little was lost, and a clearer focus gained.

The story of SMPY's rapid development during the next several years is recorded in many professional articles and media releases and in subsequent books: Keating (1976); Stanley, George, and Solano (1977, 1978); George, Cohn, and Stanley (1979); Fox, Brody, and Tobin (1980); Bartkovich and George (1980); and Benbow and Stanley (Note 1). As the identification phase increased, so did educational facilitation.

EDUCATIONAL FACILITATION

The procedures utilized have been summarized by Stanley (1978a, 1980), Benbow (1979), and in several other papers. SMPY's approach is generally accelerative in nature. We promote grade skipping, taking Advanced Placement Program examinations, and entering college early, (Stanley & Benbow, 1982). The effectiveness of these options has been validated longitudinally (Benbow, 1981). We will discuss these intervention strategies and their evaluation below.

[1]SMSPY suggested that potential contestants should have scored in the upper 5% of national norms in the relevant subject-matter area on standardized test batteries already administered in their schools.
[2]That is the largest discrepancy found in the ten talent searches to date. The staff of SMSPY ascribed it, at least in part, to differential recruitment in this quickly arranged initial talent search and/or the almost chaotic conditions the first time—too crowded, much required shifting of test booklets from one examinee to another, etc. The girls may have been less robust in the face of that confusion than the ablest boys.

One of the first approaches to facilitate the education of some extremely precocious students identified by SMPY was to have them enter college early. Many did and have now graduated. What happened to these students? We will focus on the first appreciable number of extremely young college graduates, those of May or June 1977: five at Johns Hopkins, one at Brooklyn College, and one at George Washington University (see Nevin, 1977; "Smorgasbord," 1977). One of these, Colin Farrell Camerer, finished his work for the B.A. degree in quantitative studies at Johns Hopkins at the end of the first semester of the academic year 1976–77—officially, as of January 1977—after only five semesters. Born December 4, 1959, he was barely 17 years old then. He had attended precollege grades K–6, 8, and 11. After serving as associate editor of a weekly newspaper until September 1977, he went to the University of Chicago and earned his M.B.A. degree at age 19 and Ph.D. degree at barely age 22. While still 21 years old he became an assistant professor in the Graduate School of Management at Northwestern University and a consultant to business.

Another young graduate from Johns Hopkins was Eugene William Stark. His baccalaureate in electrical engineering (emphasizing computer science) was received in late May, a month and a half before his 18th birthday on July 10. That fall he enrolled as a graduate student in electrical engineering (still stressing computer science) at MIT, where now he has almost completed his doctorate.

Even younger than Stark by a month and a half (born August 31, 1959) was Paul Frederick Dietz. He was graduated from Johns Hopkins in electrical engineering, Phi Beta Kappa, and went that fall to Cornell University as a graduate student in computer science. Well along with his doctoral dissertation for the Ph.D. degree, in the fall of 1981 he became a faculty member in computer science at the University of Southern California.

The fourth Johns Hopkins graduate that 1977 spring was Michael Thomas Kotschenreuther, born November 24, 1958. He was elected to membership in Phi Beta Kappa as a junior and took high honors in physics. Still age 18, he went that fall to Princeton as a graduate student in theoretical plasma physics. He finished his doctorate there at barely age 24 and went to the University of Texas at Austin to do research in his field. Stark, Dietz, and Kotschenreuther each won a 3-year National Science Foundation (NSF) graduate fellowship, a signal honor.

The fifth Johns Hopkins graduate was Robert Scott Addison, born January 14, 1958. Having majored in mathematics and played excellent chess and bridge nationally, he chose not to enter graduate school, but instead took a position as a data analyst.

Eric Robert Jablow, born March 24, 1962, received his B.S. degree in mathematics, *summa cum laude,* from Brooklyn College in June 1977. Reportedly, he was the youngest graduate of the City Colleges of New York (Brooklyn, CCNY, Hunter, and Queens) in their entire history. Also awarded a 3-year NSF graduate fellowship, he enrolled as a graduate student in mathematics at Princeton that fall at age 15½, apparently the youngest graduate student ever admitted there. He completed his doctorate at age 20.

Mark Toleff Jacobson, born August 7, 1958, received his baccalaureate in mathematics and mathematical statistics (Phi Beta Kappa) from George

Washington University, Washington, D.C., in June 1977. He also won a 3-year NSF graduate fellowship for his graduate studies in statistics at Stanford University that fall. Now he is working on his doctoral dissertation.

Contrary to the unfortunate case of early-graduate Karen Hermann (Hermann, 1981; Stanley, 1982), none of the six who entered graduate school dropped out, changed fields, or transferred. On the other hand, and not surprisingly, none was able to meet all doctoral requirements in 4 years. Camerer, youngest of the group except for Jablow, came the closest by completing all requirements for the Ph.D. degree on November 10, 1981, a little less than a month before his 22nd birthday. In other words, he finished work for the Ph.D. degree during the same calendar year he would "normally" have been a young-in-grade college graduate, rather than the 8 years later that is typical of the usual (30-year-old) recipient of a Ph.D. degree in scientific fields. Having these 8 vigorous years in which to further his professional career may mean that he will be a tenured associate or even full professor at about the same time he would otherwise have been merely beginning his postdoctoral career.

It seems likely that the remaining three will also complete work for their doctorates within the next several years. It is worth noting that each chose a major research university: Chicago, Cornell, MIT, Princeton (2), and Stanford. Also, each chose a difficult doctoral field: computer science, economics, electrical engineering, mathematical statistics, mathematics, and physics. Their achievements are particularly notable when one considers that all seven were "local boys," found in SMPY's early days when the talent searches involved chiefly the Baltimore vicinity and had little national visibility. Their progress is eloquent testimony to the power of freeing up curricular opportunities for the exceptionally able youths present in every sizable population area. Curricular flexibility, not special programs for the intellectually gifted, figured most strongly in their advancement. Their educational acceleration involved individually tailored combinations of skipping grades, taking college courses on the side while still in high school, scoring high on Advanced Placement Program examinations, entering college early (not one of the seven had a high school diploma when he started), taking heavier-than-average course loads in college, and the like. What was done readily and informally for them by the small SMPY staff during the early days of the study is now being carried out more efficiently and, quite probably, more effectively for a far larger and generally even abler group of such precocious students across the country.

Yet, in retrospect one wonders whether it will be possible to capture again the first faint blushes of Camelot. We had rather little to offer these valiant, sturdy members of the vanguard except radically early admission to college. Eric Jablow "simply" went from the sixth grade of a Brooklyn (New York) public school to become a full-time student at Brooklyn College when age $11^1/_2$. During his first semester there he took a standard course load, including *third*-semester calculus, and made all A's. The next semester he went on to differential equations and mathematical analysis. We of SMPY had encouraged him to become a full-time college student, but provided no tutors or other support system except our availability by telephone, letter, or visit when desired. Nowdays we would probably try to bridge the transition into college by several years of intermediate education (see

Benbow & George, 1979). We believe that would have beneficial social effects and produce a better general-education base, but in the long run would it better accomplish specialized goals for major fields of study? We think so, and of course will be making all feasible comparisons in order to modify our views as the now rather rapidly accumulating evidence may suggest.

The strongest moral we can draw is that each exceptionally able youth must be treated on an individual basis. Full consideration must be given to his/her pattern of abilities, family circumstances, local opportunities, and—most of all—the youngster's own considered assessment of the situation and of his/her eagerness to move one way or another. Getting the young student fully into the educational decision-making process early, while in elementary school, seems crucial. Many sensitive parents and teachers often know that intuitively. Others must train themselves to consult the youth about his/her wishes on all important decisions after providing the necessary information and suggesting ways to examine the decisions in line with the student's emotional, social, and intellectual development.

The rewards of this process can be great for the students, their parents, and their educators. We see definite signs of a national awakening in these respects. Of course, the root of the whole procedure must be early, valid identification of youths who reason extremely well mathematically so that they can be evaluated and helped educationally and personally over a number of years as they move toward becoming full-time students at a first-class college or university.

Wolfson I

Besides the students who went to college early, there are other special-interest groups to follow. Foremost among these are the students in SMPY's first special, fast-paced precalculus mathematics class. This began rather quickly and somewhat informally in June of 1972 and continued on Saturdays during the school year 1972–1973 and, for the most successful students, into August 1973. Joseph R. Wolfson was the instructor of this and the similar class the next year, so we call the pioneering class Wolfson I.

Although the goals for this group were impressive, they were met successfully (see Fox, 1974). The original Wolfson I class surpassed SMPY's expectations. In 12 to 14 months, eight students completed 4½ years of mathematics, two completed 3½ years, and six completed 2 years.

This group has been followed in depth (Fox, 1974; Stanley, 1976, pp. 156–159; Benbow, Perkins, & Stanley, Note 2), and the success of its 10 top achievers (out of the 22 enrolled for an appreciable part of the time) is striking. Nine of them accelerated their educational progress by at least a year. One was Colin Camerer, mentioned previously, who graduated from Johns Hopkins at barely age 17, and from the University of Chicago with an M.B.A. degree at age 19, and a Ph.D. degree in finance at age 22.

Two others from the Wolfson I class received their bachelor's degrees at age 18, and two at age 19. One of the last two also received a master's degree concurrently with the baccalaureate. Although the seven boys in that group tended to move considerably faster educationally than the three girls, the latter also did splendidly, including: a bachelor's degree in computer engineering from the University of Michigan a year ahead of her age group, a bachelor's degree in Russian Studies from the University of Virginia a year early, and a bachelor's degree in architecture from Princeton.

The top group has been compared with three other reference groups: those who dropped out of the class at the end of the 1972 summer, those who stayed in the class but had to be provided a different instructor in order to move at a slower rate, and those who were invited to join the class but who declined. Even though the students in the comparison groups were highly able and made good-to-excellent college records, the students in the top group were outstanding relative to them. The great difference in educational acceleration between the top 10 and the others was perhaps the most impressive finding thus far (see Benbow et al., Note 2). It seems likely, too, that the extent and quality of their graduate work will differentiate the groups strongly.

Wolfson II

During the summer of 1973 a second fast-paced precalculus class was also formed, to be taught by Mr. Wolfson. Instead of consisting chiefly of students who had recently completed the sixth grade, it enrolled mainly those who had completed the eighth grade and had already taken a year of algebra (see George & Denham, 1976). Follow-up results for this group are somewhat less impressive thus far than those for Wolfson I, but nevertheless the participants in Wolfson II seem to have made vastly better educational progress than have the equally able nonparticipants (Benbow et al., Note 2). One of the former completed his bachelor's degree at Johns Hopkins at age 17. Another (David Alan Meyer) earned the B.A. and M.A. degrees in mathematics concurrently at barely age 20, winning a Churchill Scholarship to study mathematics at Cambridge University for a year. One highly motivated boy received his bachelor's degree at age 18 (Phi Beta Kappa) and his master's at age 19 in the mathematical sciences, both from Johns Hopkins. Another received his bachelor's and master's degrees at age 20, along with Johns Hopkins's top scholarship-activities award. Three were graduated from MIT, one of them a year younger than is typical.

Because the students in Wolfson I tended to achieve somewhat better than the students in Wolfson II, we believe it desirable to intervene educationally before the first year of algebra occurs, on behalf of youths who reason exceptionally well mathematically at that time. The slow-paced 135 to 150 hours of Algebra I in a regular school class are far too many for this type of student. As a result, those classes may lead to poor attitudes toward mathematics and improper study habits.

Four special calculus classes

SMPY has also pioneered, since 1974, fast-paced college-level calculus classes for one 2½-hour period per week for approximately 30 weeks during the school year. The purpose is to help the youngsters accomplish the year of high-school calculus concurrently with the first college year of that subject.

The success of these classes has been well documented (Mezynski & Stanley, 1980; Stanley, 1976; Mezynski, Stanley, & McCoart, Note 3). They are powerful supplements for high school calculus. SMPY's model can be adopted readily by college mathematics departments to help (prior to full-time college) youths who reason extremely well mathematically to score high on the College Board Advanced Placement Program's higher-level (BC) college calculus examination.

Other fast-paced mathematics programs

During its first decade, SMPY experimented with many ways to help excellent mathematical reasoners learn precalculus mathematics far faster and better than is usually possible in their regular school. Stanley (1976) analyzed and discussed some of the early efforts, besides the ones already mentioned.

Bartkovich and Mezynski (1981) set forth the rationale and results of the 1978 and 1979 summer sessions SMPY conducted on the Johns Hopkins campus for young nonresidential students. In about 40 hours of mentor-led study, the typical enrollee learned 2 school years of precalculus mathematics beyond where he/she started. The range was from mastering first-year algebra to completing the entire $4^1/_2$-year precalculus sequence from Algebra I through half a school year of analytic geometry.

Various courses for students commuting to Baltimore continued at Johns Hopkins and, with its assistance, elsewhere during academic years and summers. In the summer of 1980 Center for the Advancement of Academically Talented Youths (CTY) launched its first set of 3-week residential academic programs in mathematics, writing skills, and other subjects. These were offered again in 1981 to a total of 221 students—most of them 12- or 13-year-old ex-seventh graders—from all over the country, though chiefly from CTY's Mid-Atlantic talent-search area; 126 took mathematics.

During the summer of 1982, approximately 700 highly able youths enrolled in one or two of the four 3-week residential sessions conducted by CTY.

Like all of SMPY's and CTY's special classes, these are strongly academic and oriented toward the subject matter of high school and the first year of college. None involves the usual "gee-whiz" mathematics or "fun with science"/"fun with games" approach that characterizes most other out-of-school programs for mathematically talented youths. Each student studies only one subject for the 3 weeks, 5 or 6 hours per day, $5^1/_2$ days per week. Progress is judged largely by objective criteria, especially standardized tests.

Interaction with more than 200 of one's intellectual peers is a main feature of the residential programs, in class and out. All who attend are at least in the upper one-half of 1% in ability mathematically and/or verbally, compared with their age group in the United States. Most have never before had much contact with others of similar intellectually capacity. For nearly all, it is a thrilling experience, both educationally and personally.

The "diagnostic testing followed by prescribed instruction" mentor model devised by SMPY (Stanley, 1978b) minimizes unproductive repetition and maximizes speed and level of mastering the subject. Students are not taught didactically. Instead, their learning is paced by brilliant mentors, some of them only a few years older than their students but much further along in the subject matter. For example, during the summer of 1981 the 126 mathematics students were placed in seven classes grouped homogeneously by how much mathematics each student already knew, as determined by means of the Educational Testing Service's Cooperative Achievement Tests in mathematics. Those who started the summer program knowing the most mathematics were placed in the most advanced section to concentrate on intermediate precalculus subjects such as college algebra, trigonometry, and analytic geometry. In the slowest section the students worked initially on Algebra I. For each section there was a chief instructor-mentor with at least one assistant, a ratio of about 10 students per mentor. The average student accomplished 2 new years of mathematics. By the fall of 1981 quite a few of the 126 were ready for twelfth-grade honors advanced-placement calculus as they entered the eighth grade!

These programs are recent. It will be interesting to see what will happen to these students later in high school and in their adult lives.

THE TALENT-SEARCH PARTICIPANTS

Until now we have discussed mainly the students who were especially facilitated by SMPY. But what has happened to the students who participated in SMPY's talent searches, some of whom were and some of whom were not especially helped by SMPY? The students in SMPY's first three talent searches were followed up at the end of high school and their progress evaluated. Cohn (1980) studied the first 214 such students to graduate from high school and Benbow (1981; Note 4) the remaining 1974 students. Their backgrounds at the time of the talent search have been previously documented (Keating, 1974; Benbow & Stanley, 1980, 1982b). As seventh or eighth graders they were doing well in school and mathematics; liked school, mathematics, and science; and came from homes where the parents had been rather well educated.

Benbow (1981) provides the following summary of (a) the high school status of SMPY's students in the first three talent searches who scored then better than a national sample of high school females and (b) the evaluation of SMPY and its procedures:

> SMPY students achieved academically at a superior level in high school, were similar to the Terman group, became accelerated in school placement by use of the options recommended by SMPY (mainly through its newsletter), valued educational and scientific endeavors, and felt that SMPY had been of some help to them. Sex differences in mathematical ability and achievement were also noted. Furthermore, sex differences in achievement in high school could be accounted for to an appreciable extent by the difference in mathematical reasoning ability in the talent search.
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> Acceleration was deemed a viable alternative for educating gifted children. In addition, the predictive validity and long-term reliability of the Scholastic Aptitude Test were determined to be high. Its use was shown to be an effective way of identifying students in the seventh grade who will achieve academically at a superior level in high school.
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> Finally, the Study of Mathematically Precocious Youth was evaluated. It was shown that it had helped educationally the students it identified, while not detracting from their social and emotional development. SMPY was seen as fulfilling its stated purpose: discovery, description, and development of youths who reason exceptionally well mathematically (pp. 268-269).

SEX DIFFERENCES

From the first talent search on, a sex difference was found on the SAT-M, a test of mathematical reasoning ability (Benbow & Stanley, 1980b; 1981). Students with superior mathematical reasoning ability are needed in the sciences and engineering. SMPY can identify such students, but has found that far fewer girls than boys score at the high levels of mathematical reasoning ability measured by the SAT-M. For example, at the 500 SAT-M level (approximately the average of college-bound 12th-grade males) SMPY males outnumber SMPY females about 2 to 1. At the 600 level there are four boys to every girl. At 700, the ratio is about 15 to 1. This difference cannot be explained by the previously held notion that, since boys tend to take more mathematics in high school than do girls, they consequently have better mathematical reasoning ability. Certain socialization explanations are also implausible (Benbow & Stanley, 1981; Fox et al., 1982).

The development and consequence of this sex difference in high school have been investigated longitudinally (Benbow & Stanley, 1980b; 1982a). It was found that the abilities of the males developed more rapidly than those of the females. Moreover, sex differences in high school favoring males were found in participation in mathematics, performance on the SAT-M, and taking of and performance on mathematics achievement and Advanced Placement Program examinations. In contrast, SMPY females received better grades in their mathematics courses than the SMPY males did, and few significant sex differences were found in attitudes toward mathematics. It was also established that a relationship between the sex difference on SAT-M and some sex differences in mathematics achievement may exist.

Recognizing these sex differences, SMPY has tried to devise suitable intervention strategies. For example, in 1973 a special program was implemented (Fox, 1976); moderately gifted seventh-grade SMPY girls were invited to an accelerated mathematics program in algebra during the summer of 1973. In addition to providing fast-paced algebra, this program catered to social needs. It offered interaction with female role models who had careers in the mathematical sciences, and encouraged the girls to study advanced mathematics. The girls who successfully completed the program (i.e., those who were placed in Algebra II that fall) did take more advanced mathematics in high school and college (Fox, Benbow, & Perkins, Note 5). That was, however, the only major difference between this group of girls and an equally able group not invited to attend the program. No effects were found for the girls who attended the accelerated algebra program but were not successful. Clearly, an early intervention strategy can improve the participation of girls in higher level mathematics if they are able enough to succeed in such a program. Unfortunately, several in this study may not have reasoned well enough mathematically to benefit much from the speeded-up special training.

We were also interested in what consequences a sex difference in mathematical reasoning ability discovered in the seventh grade had for achievement in high school science (Benbow & Stanley, in press); we found that mathematically pre-95% of college-bound male 12th graders at age 17 or 18—i.e., at least 700 on the science and participate in it at a much higher than average level. Many sex differences were found, however. Far more SMPY males than females took a physics course in high school, took the high school and college-level achievement tests in science, and planned to major in college in physics and engineering. Furthermore, SMPY males performed better than SMPY females on achievement tests measuring knowledge and understanding of biology, chemistry, or physics. Some of the sex difference in the taking of and performance on these tests could be accounted for by the females' lower mathematical reasoning ability in the seventh or eighth grade. Moreover, no pervasive sex differences in attitudes toward science were detected. The only areas in which we found large sex differences in attitudes and participation were physics and engineering.

Clearly, SMPY has discovered a set of sex differences in science and mathematics achievement that seem related to the sex difference in mathematical reasoning. Of course, much further research is sorely needed.

THE "≥ 700M BEFORE AGE 13" GROUP

A new activity for SMPY, begun in the fall of 1980, is searching nationwide for youths born not earlier than 1968 who score higher on SAT-M before 13 than do 95% of college-bound male 12th graders at age 17 or 18—i.e., at least 700 on the 200 to 800 College Board score scale. Later, this was liberalized a bit because the SAT is not administered each month of the school year, and not at all during the summer. The revised rule is that for every month or fraction of a month beyond the 13th birthday the youth must earn 10 points above 700. For example, at age 13 years and less than 1 month this requires 710. During the first year of this program, we found 63 boys who qualified, but unfortunately no girls. By March of 1983 this had risen to 181 boys and 12 girls.

The three SAT scores of the first fully tested 69 male and 3 female high M scorers and only the SAT-M score (730) of a Guatemalan boy, who did not take SAT-V or Test of Standard Written English (TSWE), are shown in Table 2. Also included for comparison are the scores of other girls found in January of 1978, 1979, or 1980, before the present ≥700M search began.

The 70 boys' mathematical reasoning scores ranged from 700 (14) to 790 (1), their median being 720; 97% of college-bound 12th-grade males score less well than that. A 780 was earned by Eugene Volokh of California when only 10 years 1 month old. Born in 1968, he is a full-time computer science and mathematics major at UCLA whose achievements have been recognized in the *Wall Street Journal* (Walters, 1981) and elsewhere. The following four are also full-time college students: Jay Luo, who received his B.S. degree in mathematics from Boise State University in Idaho in May 1982, a month or so after his 12th birthday; Michael Coleman Miller, who completed his sophomore year at Hillsdale College in Michigan in the spring of 1982 at age 13; David John Ruffolo, who became a full-time student at the University of Cincinnati in the fall of 1981 at age 13; and Kenneth Steven Weiss, top V + M scorer in CTYs large talent search of January 1981, who entered the University of Maryland (College Park) in the fall of 1981 at age 13 on a 4-year scholarship.

TABLE 2
FREQUENCY OF SAT SCORES OF "≥700M BEFORE AGE 13"
BOYS (B) AND GIRLS (G)

Score Scale	Math[a]		Verbal		TSWE[b]	
	B (70)	G (10)	B (69)	G (10)	B (69)	G (10)
790	1					
780	2	1				
770	1					
760	5	3				
750	6	1	1	1		
740	4	3				
730	11					
720	9					
710	14	1		2		
700	17	1				
665–695			2			
635–665			9	2		
605–635			1	1		
575–605			7		15	3
545–575			8		13	4
515–545			10	1	19	1
485–515			6		6	
455–485			11		8	1
425–455			2	1	1	
395–425			6		3	
365–395			1	1	3	1[c]
335–365			3			
305–335			2	1[c]		
275–305						
245–275						
215–245						
(185)–215					1[d]	

[a]By the definition of these groups they contain no SAT-M scores below 700.
[b]The TSWE score scale runs from 20(0) to only 60(0).
[c]This girl (who scored 760M, 330V, and 38 TSWE) had recently immigrated from Japan to the United States.
[d]This boy seems not to have made any effort to score well on the Test of Standard Written English. His other SAT scores were 750M and 340V.

On SAT-V the 69 boys' scores (310V to 750V, the latter Weiss) were far more variable than the 90-point-range SAT-M scores. This was also true for the TSWE. The median SAT-V score was 530, higher than 81% of college-bound 12th-grade males score. The median TSWE score was 53, better than that of 82% of college-bound 12th-grade males. Therefore, although these brilliant mathematical reasoners did extremely well, relative to their age group, on the two verbal tests, most of them were considerably more developed in mathematical aptitude than in verbal aptitude before age 13. The differences in the scores appear less sharp when one notes that the equivalent of a 700 score on SAT-M is an SAT-V score of 630, not 700. This is because only 5% of college-bound 12th-grade males score that high. Thus, the two score scales are not comparable directly, but only through the percentile-rank norms. For a rough comparison of a highly able boy's V score with his M, add 70 to the former. (For college-bound 12th-grade males the respective *means* are 493M vs. 431V, a 62-point difference.)

These exceptional students are receiving massive doses of individual educational counseling and are being given the option to partake in many educational opportunities. For example, although a number of the 73 were discovered too late to attend either of the 3-week residential summer programs conducted separately by Johns Hopkins University and Duke University during the summer of 1981, 47 did attend one or (in three instances) both of the 1981 programs. Two others had attended the 1980 summer program. Forty-seven of these 49 attenders of at least one session took three intensive weeks of mathematics. The other two were already beyond the precalculus state in their own schools.

To these 49 mathematics-accelerated youths must be added three of the full-time college students, all of whom are far beyond precalculus, and the Guatemalan boy, who attended no summer sessions, but in May of 1981 at age 12 earned the highest obtainable grade (5) on the higher-level (BC) Advanced Placement Program examination covering the first year of college calculus. That brings the number of persons with mathematics training far beyond their school age-mates up to at least 53. The staff of SMPY expects that many of the ≥700M group not yet through the first year of college calculus will accomplish that by Advanced Placement Program examination in May 1983, while most of them are still eighth or ninth graders—i.e., they will demonstrate mastery of difficult mathematics 4 or 5 years beyond their age.[3] Also, most of those not yet past precalculus will probably study mathematics in CTY's summer 1983 programs.

Following up these youths who reason so well mathematically should shed considerable light on the upper limits of learning mathematics and related subjects well and on rapid acceleration in course and grade placement. It is somewhat analogous to working in ultrahigh energy physics in order to test theories developed at lower energy levels.

A major conclusion of SMPY's first decade is that gifted students need to be identified early and, through curricular flexibility, helped educationally in major ways. We feel confident that the second decade will continue to see our principles, practices, and programs validated and increasingly disseminated. Thanks substantially to The Spencer Foundation, our first 10 years have laid a firm basis for further progress.[4]

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[3]In May of 1982 12 boys in the "700–800 M Before Age 13" group scored 5 on the AP BC calculus examination. They ranged in age from 12 to 14.

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