Extreme Measures for the Exceptionally Gifted in Mathematics and Science

DANIEL P. KEATING and JULIAN C. STANLEY[1]
The Johns Hopkins University

What does one do for a junior high school student who already knows more mathematics than his teacher? The question is not as implausible as it may seem at first glance. From preliminary work with seventh, eighth, and young ninth graders at Johns Hopkins University, it is clear that a sizable number of these youngsters score extremely high on the College Entrance Examination Board (CEEB) Scholastic Aptitude Test-Mathematical (SAT-M) and Mathematics Level I Achievement Test (M-I), often higher than their math teachers probably would. The same is true for the general science knowledge of some students this age. The group for whom new programs are urgently needed is expanded greatly if one relaxes the criterion only slightly. Rather than specifying "Know more math or science than their teachers," substitute: "Know more math or science than the average high school senior applying to college." This group of 12 to 14 year olds is, as will be seen later, quite substantial.

The answer to the initial question suggested by this preliminary work is: almost anything, if it is different from the traditional age-in-grade sequence. Certainly, some types of educational facilitation are better than others. But the necessity of doing something is evident from informal interviews with such students. Boredom and frustration are inevitable, although expressed in quite different ways from student to student—rebelliousness, apathy, excessive dutifulness, showing off, and so on.

Searching for precocious students

Before proceeding to some specific solutions for individual students, let us examine the extent of the problem. Under a five-year grant from the Spencer Foundation, the authors and Mrs. Lynn Fox began searching last fall for junior high school students who were exceptionally precocious mathematically and/or scientifically. The search was initiated rather informally, testing students recommended by teachers, parents, or, occasionally, previously tested peers. Although several outstanding youngsters were discovered in this fashion, it soon became clear that a more formal and extensive testing procedure was needed if many of the students working at this very high level were to be located. Accordingly, a contest sponsored by the project in conjunction with the Baltimore Science Fair was held; substantial cash prizes for the high scores on a math test and a science test were offered.

No official screening of students entering the contest was conducted, but it was recommended that the student's percentile ranks in arithmetic on nationally standardized tests (such as the Iowa Tests of Basic Skills) be at least above 95, and preferably 98 or 99. It was also announced that the tests would be on a college level, and thus extremely difficult for most seventh and eighth graders.

Of the 526 students (seventh, eighth, and 13 year old ninth graders) who registered for the math test, 396 showed up. Of 226 science entrants, 192 came. Apparently, the depletion resulted from the students' appraisal of the practice materials sent prior to the testing. Many students took both math and science, of course. The College Board's SAT-M and its Math Level I achievement test were used for the math contest, and the Sequential Tests of Educational Progress, Series II (STEP II) Science, Forms 1A and 1B for the science contest.

The investigators' suspicion that there are many quantitatively able junior high students was amply confirmed. On SAT-M, 89 students scored at or above 540, which is about the 78th percentile of male high school seniors, and 41 students scored 620 or above, which is about the 91st percentile. The total distribution is shown in Figure 1. On M-I, the situation was very similar: 35 at or above 540, about the 37th

Table 1

High Scorers in Mathematics Testing

Rank	SAT-M	M-I	M-II	Date of Birth	School Grade
1	790	770	750	4-27-58	9*
2	780	720	720	10-25-58	8
3	710	730	800	8-31-59	7
4½	740	660	670	1-18-60	7
4½	680	720	690	11-02-58	9*
6	740	630	620	1-14-58	8
7½	730	620	610	7-05-58	9*
7½	710	640	690	7-02-58	8
9	670	660	620	7-10-59	8*
10	670	610	710	11-24-58	8

Note: College Entrance Examination Board Scholastic Aptitude Test—Mathematical, Mathematics Level I and Level II Achievement tests, converted scores. Rank based on SAT-M + M-I, administered March 4, 1972. M-II was administered April 22. *Boy had skipped a grade in school.

percentile of high school seniors with seven or more semesters of high school math, and 10 at or above 620, the 65th percentile. In Table 1 are listed the SAT-M, M-I, and Math Achievement Level II (M-II) scores of the top 10 students. (The M-II scores are from a subsequent testing.)

The science test scores were also excellent. When the scores of Forms 1A and 1B were added together, it was found that 27 students had scored 100 or higher (out of a possible 150), which is the 73rd percentile of sophomores at a typical college tested in the spring. Continuing: 15 scored at or above 110, the 87th percentile; 7 above 120, the 94th percentile; and 2 above 130, the 98th percentile. The complete distribution is shown in Figure 2.

The implications are clear. There currently exists a significant number of students who, even before entering high school, already know much of the math and science they will supposedly be "taught" in high school. For such junior high students the typical academic situation is anything but beneficial. This is not to denigrate the junior high schools, for clearly they were not designed to deal with a 12 year old seventh grader who scores 710 on SAT-M, 730 on Math I Achievement (the third ranking scorer in Table 1), and 800 on Math II. This same boy was the winner of the science contest, with a score that ranked him at the 99th percentile of end-of-year college sophomores in general science knowledge.

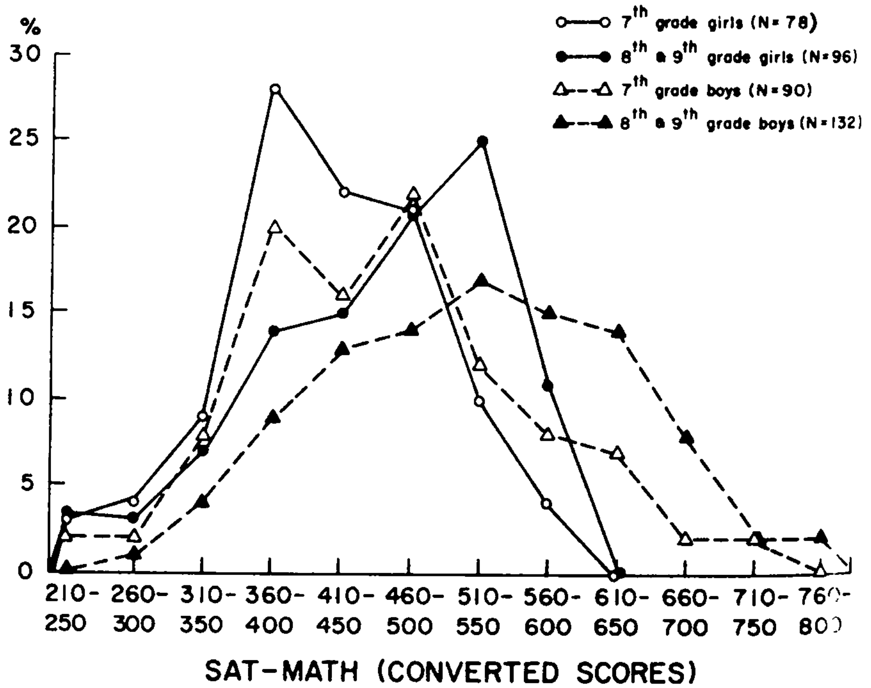
Forty-three students who did very well on the first testing were called back for a test of verbal development. It was not expected that they would be as advanced verbally as quantitatively, but it was important that there not be a drastic imbalance if they were to function successfully in courses or programs vastly more challenging than those to which they were accustomed. The median SAT-M score of this group was 658, about the 89th percentile of male high school seniors taking the test in 1969-1970. The median score of the same 43 students on SAT-Verbal was 549, about the 79th percentile. Although there is about 0.4 of a standard deviation difference between the quantitative and verbal scores of the group on these norms, these students are clearly able verbally. Further tests showed that those at the top of the group were as well prepared in most areas to do successful work in a *selective* college as the average freshman, and in at least one or two areas much better prepared than the average freshman.

Radical acceleration

Consider the cases of two students who were radically accelerated.

When Bill was twelve years old and in the seventh grade, he was "discovered" by an astute computer

Figure 1: Distribution of SAT-M scores of 396 students for four grade-sex groups



scien : teacher at the university who oticed a young student spending a great deal of time around the computers and constantly asking questions. Shortly thereafter, he was *answering* other students' questions about basic programming. Due to Bill's interest and evident ability, it was eventually decided that he should take the College Board exams a year later. His scores were SAT-M–669; Math Achievement Level I–642; Math Achievement, Level II–772; Physics Achievement–752.

It was clear that something other than merely continuing on into the ninth grade was advisable for Bill. The decision, chosen from a number of alternatives and made with considerable reservations, was that Bill should begin college the following school year. He would take those subjects in which he seemed ablest and most interested. The speculation was that he might make mostly B's and C's and occasionally an even lower grade, but that perhaps the intellectual stimulation would be worth the shift. If he did not do reasonably satisfactory college work, he could return to high school after a semester or two.

In the fall of 1969 he enrolled for honors calculus, sophomore general physics, and introduction to computer science, a 12-credit load. This would be a disastrous set of courses for the usual beginning freshmen, but it was clear that Bill was better prepared for them than for Shakespeare, political science, and other such courses. His success exceeded all expectations. He made a B+ in honors calculus, an A in sophomore physics, and a very high A in computer science. His gradepoint average was 3.69, where 4.0 is a straight A. It was obvious that, intellectually at least, Bill had found his place.

His success has continued well beyond this first semester. Bill has now completed his junior year, and he plans to have a B.A. degree and a Master's degree in computer science by the time he is 17½ years old. Then he will go on for a Ph.D. degree in computer science. Bill has already taken the Graduate Record Examinations, once in April as a fourteen year old freshman and once in June at age fifteen after completing his sophomore year. The first time around, Bill scored 800 on the quantitative section and 630 on the advanced test in physics. On the second try Bill scored 750 on the advanced test in mathematics and 720 on the quantitative aptitude section.

Where did Bill's exceptional talent come from? Both of Bill's parents are very intelligent, but neither has had any special training or interest in mathematics or science, nor have they specifically tried to tutor Bill in them. Bill's mother reports, however, that he has "studied physics seriously since he was three." Whether that age is precise is relatively unimportant; it is undoubtedly true that he was greatly interested and extremely precocious in math and science throughout elementary school.

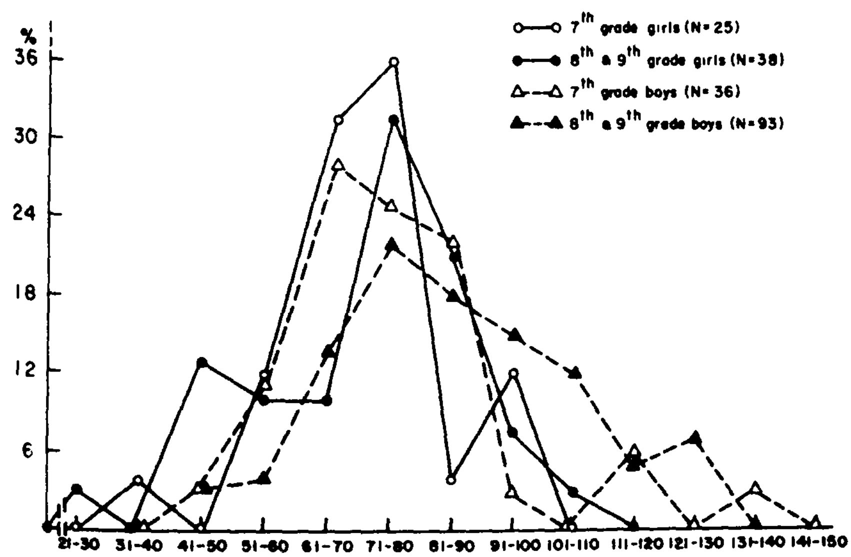
One might argue from the above that Bill is indeed an exceptional student, so exceptional that his case necessarily came to the attention of individuals who could make the required special arrangements. It would be comforting to believe that this would happen most of the time in similar circumstances, but that does not appear to be the case. Consider Eric, our second "radical accelerate."

Although Bill was clearly able to do work far beyond his age-in-grade level, he dutifully performed the tasks required of him in the seventh and eighth grades. Eric, on the other hand, was greatly dissatisfied with his educational situation. He was bored with school and did not hide the fact. This in itself did not endear him to school personnel, and his ease in doing assignments engendered resentment among his classmates. His scholastic talents were evidenced, however, by his outstanding College Board scores. At age 13 years, 2 months, Eric earned scores of 716 on the Scholastic Aptitude Test, Mathematical and 722 on Math Level II achievement. Two months later, he scored 726 on the CEEB physics achievement test and 525 on the chemistry achievement test. Eric had had no formal instruction in physics, and only a brief introduction to chemistry.

The problem of facilitating Eric's further education was complicated by his social difficulties in school. But, because of Bill's earlier success, it was again decided that entering college in the fall was a reasonable course, though with even stronger reservations than had attended Bill's entrance.

Eric's first-year performance was no less encouraging than Bill's had been the year before. His first-semester gradepoint average was 3.75, and his year gradepoint average was 3.59 (on a 4.0 scale), which included A's in general physics, honors cal-

Figure 2: Distribution of STEP II Science scores for four grade-sex groups



culus, and programming language. An unanticipated bonus was the disappearance of his adjustment problems. The rebelliousness he had shown only a year earlier was gone, and he quickly reported that he was extremely satisfied with his new situation.

Eric completed the sophomore year with a 3.65 GPA and extra course credits at age 15 1/2. He is well on his way to a distinguished B.A. with two major fields, mathematics and philosophy. There is every reason to believe that he will earn a Ph.D. degree in mathematical logic at age 20 or 21 or even earlier. In his sophomore year he moved into a campus dormitory and seems to have adjusted extremely well to the huge jump from eighth grade to the first year of college. He has since moved into an apartment which he shares with another undergraduate.

Eric's case raises an issue which deserves closer attention. The question is frequently asked, "But have you thought about the social and emotional development of these students?" While radical acceleration worked well for Eric, is this atypical? The possible disruptive effects of academic acceleration have been studied carefully by a number of researchers (e.g., Coombs, 1957; Oden, 1968; Pressey, 1949, 1967; Terman & Oden, 1947, 1954). The general conclusion seems to be that the disruption is not as great as many would expect. One neglected aspect, however, is the possible harmful effects on a highly precocious student's personal development if he is forced to endure many years of academic boredom and intellectual frustration. Eric's case may indicate that this latter problem is not insignificant.

Another frequently voiced concern is that these students will be intellectually narrow because of their concentration on quantitatively oriented courses to the exclusion of the humanities and social sciences. This, too, is an important consideration. It would not be well to "program" students into a specialized area, blithely assuming that their greatest eventual interests must lie in the same fields as their strongest early abilities.

This danger is partially alleviated by the very nature of their test scores. For an eighth grader to do well on a college level *achievement* test, it is necessary for him to have done a considerable amount of work on his own in that subject. This is in and of itself a strong indication of deep interest in these subjects that we also explore via interest and value inventories. It has been suggested, on the other hand, that these students *should* be "programed" into humanities and social sciences courses so that they may benefit from the exposure. Some who have suggested this, though, would object to a fine arts major's being required to take advanced calculus or some similar course.

The alleged narrowness may in fact be illusory. Bill and Eric, and other students like them, are quite intelligent and typically have a fairly wide range of interests. Eric, for example, has taken courses in psychology and philosophy. Any rigid program requirements would seem unwise for students of this caliber, especially because the usual B.A. degree requirements demand considerable distribution across subject-matter areas.

Less "radical" acceleration

Entering college full-time at the end of the eighth or ninth grade is a solution that will be possible for only a few students. But there are a number of other ways that youngsters who are highly precocious in math and science can move on to challenging work.

One possibility is released-time courses or evening courses during the school year. In the spring of 1972, three students in the present study took computer science at a local university, two during the day on released time and the other during the evening. All three, a 15 year old tenth grader, a 13 year old ninth grader, and a 12 year old eighth grader, did extremely well in the course, consistently ranking near the top of a large class of college students; all three earned "A" as their final grade. Summer courses are another possibility for these students. Under the auspices of this project, twelve seventh, eightl and ninth graders are taking c lege courses during the summer of 972 in mathematics, computer sci nce, chemistry, and English compos ion. Unfortunately, not all students vho would be capable of benefiting om such advanced work will live ear enough to a good college to do so. The possibility of college correspondence courses for exceptionally able junior high students who find themselves in that situation is currently under investigation. They appear feasible.

Although the percentage of students who need some radical acceleration is small, the number throughout the whole population is probably sizable. Because of the method of selection of our sample, it is not possible to make any firm predictions about the population. There are, however, just over 80,000 seventh and eighth graders in the areas represented by the students we tested. The top 25 students, who clearly require very special educational facilitation of some sort, thus represent about .03% of the population. This is obviously a minimum estimate; the actual percentage of highly mathematically or scientifically precocious youths is likely to be considerably higher. This would mean a probable minimum of approximately 3000 junior high age students nationwide.

Upon closer inspection, Figures 1 and 2 reveal a striking sex difference at the upper ends. There were no girls above 600 on SAT-M, while there were 43 boys, even though 44% of those taking the math tests were girls. In addition, 32% of those taking the science test were girls, but the highest scoring girl earned a 103 (out of 150), ranking 23rd in the group. We can at this point only speculate about this difference. As mentioned above, for a 12 to 14 year old student to do well on these tests it is necessary to have done much work on one's own in these areas. It hardly needs to be pointed out that girls in our culture are not normally encouraged to spend their spare time reading math and science books.

Differentiation of ability by sex has been studied recently by Ve y (1967), Aiken (1971), and Hav n

(197). It is not the main purpose of the present study to look at these differences, but their strong appearance in these data demands that the topic be given attention in the future. Helen S. Astin plans to discuss these and other data at an American Association for the Advancement of Science symposium on the topic of mathematically precocious youth in Washington, D. C. Dec. 28, 1972. Papers will also be presented by Julian Stanley, Lynn Fox, and Daniel Keating, and discussed by Anne Anastasi.

What the project is not

There are a number of persistent misconceptions about the nature of the project. Perhaps the most serious and most basic among these is that the goal is to locate very bright students and "push" them in math and science to "make scientists out of them." First, it is unlikely that it would be possible to do so even if one wanted. Second, the project is explicitly concerned with aiding and assisting manifest math and science talent, *not* with developing latent abilities in those areas, hence the use of achievement tests in the identification process.

Another misconception perceives the project as an attempt to develop a single program for exceptionally bright students. This again is far from the situation; flexibility and individualization have been the key concepts guiding the work with these students.

The project to date has met with varied reactions from school personnel. There has been little difficulty in working with local administrators in higher education; in fact, their reaction has been almost universally favorable. In addition, parents have thus far had few problems in working out amicable arrangements with junior high schools, such as providing released time for college courses or allowing individuals to "skip" material for which they have demonstrated competence. The greatest problems facing parents thus far have been with senior high schools. There seems to be a persistent fear among some high school principals about "making exceptions." The sensible argument, of course, is that the "exception" is already present, and what is required is a rational and productive means of dealing with the problem. This normally involves some sort of individualized "telescoping" of educational procedures for these advanced students. The experience of the parents and students in dealing with school personnel has been limited, however, and there are high hopes for continued or improved cooperation at all educational levels.

As time goes by, it is expected that a great deal more will be learned about the interests and abilities of these young people. In addition, it will be possible to make an even stronger case for the necessity of providing different, often radically different, educational opportunities for them.

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Notes

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