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INDIVIDUALIZING SCIENCE CURRICULA FOR THE GIFTED

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The argument that individuals experience different rates of intellectual development has been well established in the 20th century. Recently, Keating (1976) has shown that . . . "brightness as measured by psychometric testing implies developmental precocity in reasoning." "Students . . . selected for high scores on psychometric tests...are indeed precocious in cognitive development, and not just good 'test-takers.'" He adds: "Since, according to Piaget, cognitive development proceeds as an interaction of the organism and the environment, the brighter individual would be at an advantage moving through the successive stages more quickly." In addition, Keating's work (pp. 97-98) suggests that such acceleration should occur *within* developmental stages, such as concrete operations or formal operations, rather than across stages.1

It is only within the last few years, however, that interest among educational planners in individuals of high ability has reached the point of garnering financial support for research and development of programs aimed at meeting the educational needs of this segment of the school population. The diversity of programs, especially in science and mathematics, that has been developed since the scientific consciousness of the American public was raised abruptly by the Russian launching of the Sputnik satellite in the late 50's can be split into essentially two broad categories: enrichment programs and programs of an accelerative nature.

Enrichment, on the one hand, insures that the status of the traditional lock-step, age-in-grade passage of individuals through the school system remains unchanged. Stanley (1976b) argues, however, that many enrichment programs designed to meet the educational needs of the gifted are more likely to be "busy work," or to postpone boredom in school work to a later and potentially more crucial point in an intellectually gifted child's academic development, than to provide stimulating curricula which in fact allow for the full development of this individual's extraordinary abilities. In

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planning enrichment programs, educators tend to by-pass the recognition of developmental precocity as a component of the processes of identifying and nurturing giftedness.

Programs that are structured, on the other hand, to allow for a more rapid transit through the process of academic certification can accomplish much the same breadth of educational development as enrichment programs, while providing for greater flexibility and allowing for more prime creative time during which these individuals can later function as productive scientists and mathematicians.

The educational models developed for mathematics instruction by the Study of Mathematically Precocious Youth (SMPY) and the Intellectually Gifted Child Study Group (IGCSG) both at The Johns Hopkins University are based squarely in acceleration as the major method of providing the following three things: first, stimulating and relevant educational experiences for the gifted; second, appropriately flexible and rapid transit through the academic certification process; and third, educational credit for work accomplished, whether done at the typical age level or not. Since, even among the subpopulation of students identified as gifted, there is a broad distribution of levels of ability, as well as types of ability (verbal reasoning, non-verbal reasoning, math-reasoning, etc.), each model has been designed to meet the specific needs of individuals within these various levels and types of giftedness. Suggested alternatives to the traditional lock-step range from subject matter acceleration to individual tutorial programs. Although these models were proposed and tested for mathematics instruction, their probable applccability to instruction in the sciences is clear:

Let's look for a moment at a program that might be appropriate for a relatively gifted youngster, who, for example in the 7th grade scored at least 500 on the mathematics section of the College Entrance Examination Board's Scholastic Aptitude Test (SAT-M) and at least 440 on SAT-Verbal. His scores in both areas exceed those of the average college-bound high-school senior. Should this youngster be required to take the typical eighth grade (and in some cases 9th grade) science courses--designed to *ease* the student into the process of scientific inquiry? Considering Keating's findings mentioned earlier, we are safe in assuming that this student has entered the developmental stage of formal operations; that is, he or she has developed the reasoning structures necessary for the comprehension of scientific abstraction. In cases where only one or two such students attend a particular school system, simply allowing them to enter the highest ability classes of the natural science sequence is more desirable than holding them in age-in-grade place. These students would finish the science sequence one or two years early. They could then take Advanced Placement courses, achieve a grade of 3, 4, or 5 on the APP exam, and garner very economical college credits while still in high school. (The cost of the APP Exam is $32.00 as compared with the cost of a two-semester college science course, which can be more than $1000.00 at some private universities.) Another alternative would be for such students to take college courses in science during released time from school or at night at a local college.

In some particularly talent-rich school systems, special fast-paced accelerated classes in the sciences could be created. The feasibility of applying the SMPY's fast-paced, accelerated mathematics class model to science classes was tested in a pilot study conducted at a private school near Baltimore, Maryland, under the auspices of the Intellectually Gifted Child Study Group during the 1974-75 academic season (Cohn 1975, 1976).

Students entering the 7th and 8th grades were screened simultaneously for inclusion in a combined Algebra I/Algebra II class, as well as a Physical Principles class. Performance on the Academic Promise Test, Verbal and Numerical sections, and on the STEP Science Series II General Science test served as the basis for an invitation to participate in the special science class. Both sets of tests provided sufficiently high ceiling. Cut-off scores at least at the 95th percentiles on both the verbal and numerical aptitude tests and at least at the 50th percentile on the STEP Science test served as selection criteria. Each student who achieved at or above these criteria received a letter of invitation to participate in the fast-paced, accelerated physics class. Students are encouraged to make their own decisions regarding such participation. Parents were also counseled to resist the temptation to pressure their children into participating in the program. Five students chose to join the special science class.

The group met for two 45-minute lecture periods and one hour-and-a-half laboratory session each week, before and after regular school hours. The regular course of study was completed in about six and one-half months. This compares with five 45-minute lecture periods plus one hour-and-a-half laboratory session per week for nine months in the regular ninth grade physical principles class.

At the end of the course work, students were tested on the Cooperative Science Physics Test. In order to provide a comparison group, students in the most selective section of the regular physics course were also tested. On this standardized measure the five accelerated students performed as well as or better than the "A" students in the regular class, even though the former were one to two years younger.

Although the number of students participating in the special science class was quite small, the pattern of success replicates the findings of the SMPY and the IGCSG studies with fast-paced, accelerated classes in mathematics. The results of this pilot study strongly suggest that the SMPY model for fast-paced, accelerated classes may well be applied to science instruction for the gifted. That most of the abstract principles in physics and chemistry are representable in mathematical form lends logical consistencey to this finding. An excellent mathematics reasoner should do well in a physics course. In fact, one superb mathematical reasoner in the SMPY study (who incidentally scored 780 on the SAT-M and 620 on the SAT-V while in the 8th grade at age 13) took the College Board physics test without having taken a physics course and achieved a score of 800 (in fact, it could be extrapolated to the equivalent of 830).

The major difference between mathematics classes and science classes lies in the necessity for laboratory experience in the sciences. Labs take time. The theoretical subject matter can be covered rapidly, but some provisions must be made to allow the student to see how the theories evolve out of experimentation within the context of the scientific method. One Maryland private school has approached this problem by treating the science laboratories as experiential libraries. The head of the science department's time is scheduled such that he or she is available to supervise students who wish to do labwork during their free time. In other situations science teachers have allowed a few students to work in the lab during their study halls while the teacher was instructing another class. Thus, although lab-work represents the time-limiting factor in accelerating science education, the real question remains: How much of the lab time, as labs are usually conducted, is unnecessary for highly able students?

Let's now turn to the case of a student with amazing ability at mathematical reasoning. Such a student might score a 660 on the SAT-M at age 13. For the sake of illustration let's call her Ellen. This score is better than that achieved by 98 out of 100 college-bound seniors in high school. Her score on the SAT-Verbal test is similarly high. She attends a school in a small essentially rural county. There is no teacher available to work with her individually. Even placing her in the typical high-school mathematics sequence is inappropriate, since, if properly guided she can learn the equivalent of a year-long mathematics course in a matter of a few months at the longest. Having heard of the Hopkins studies, her parents call SMPY for guidance. SMPY has developed a tutorial strategy modeled on the Oxford-Cambridge (OX-Bridge) tutorial preceptor system (Stanley, 1977). A tutor is assigned to work with Ellen. Saturday meetings are scheduled, or if the distance is too great the tutorial is conducted by mail except for occasional meetings for stimulation and testing. The tutor is a member of the SMPY staff of tutors, who are also mathematically brilliant youths (typically, college students who have completed at least Calculus III and honors linear algebra).

The procedure is relatively simple. Since Ellen has not yet taken an Algebra I course, she is given the Cooperative Mathematics Algebra I Achievement Test. She scores 38 out of 40 on Form A. The test booklet, not the answer sheet however, is returned to her, and she is informed which problems she missed. Ellen can take as much time as she needs to re-solve these two problems. She solves both of them correctly. She is then administered the Cooperative Mathematics Algebra II test. She gets 25 out of 40 correct on Form A. Once again she is given the booklet and allowed as much time as necessary to work on the problems she missed. She gets 5 more correct. The 10 problems she still cannot solve are referenced in the Cooperative Mathematics Test Manual according to a typical Algebra I course syllabus. Ellen's tutor then carefully instructs her in these specific problem areas. When she has mastered these concepts, she is administered Form B of the Algebra II Achievement Test. She earns a perfect score. This procedure is repeated for the entire standard mathematics sequence. Letters are sent by the SMPY staff to Ellen's school administrators, informing them of her mastery of each course in mathematics that she covered and encouraging her counselors to avoid having her placed in inappropriate mathematics classes, as well as to plan ways for her to earn college credits for upper level courses.

The application and trial testing of the Ox-Bridge tutorial strategy for instruction in science is currently under consideration by the staff of SMPY.

As the work of SMPY and IGCSG continues, it becomes increasingly clear that effective educational facilitation for the gifted does not necessitate hugely expensive enrichment programs. With a little ingenuity and by breaking down the unjustified prejudice that many educators have toward acceleration, many appropriately flexible alternatives become available to help gifted students meet their educational needs. Simple subject matter acceleration provides such an alternative for youngsters gifted in one particular academic area. In particularly talent-rich school systems special fast-paced, accelerated classes can be formed. For example, eight out of the 22 members (mostly seventh graders) in such a class covered 4½ years of precalculus mathematics in 60 two-hour weekly sessions (Fox, 1975; Stanley, (1976 a). And for truly amazingly talented youngsters, the Ox-Bridge tutorial model offers stimulating and rapid-enough transit through basic and complex subject matter.

It is important to note that *none* of the alternative strategies mentioned involves self-pacing or remedial-style tutoring. The teacher or tutor in each case provides the rapid pacing necessary to cover the material faster than would be the case in a regular class.

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FOOTNOTES

1 Keating, Daniel P. (ed.)8 *Intellectual Talent: Research and Development.* The Johns Hopkins University Press, 1976. pp. 97-98.