Chapter 5

Learning Outside of School

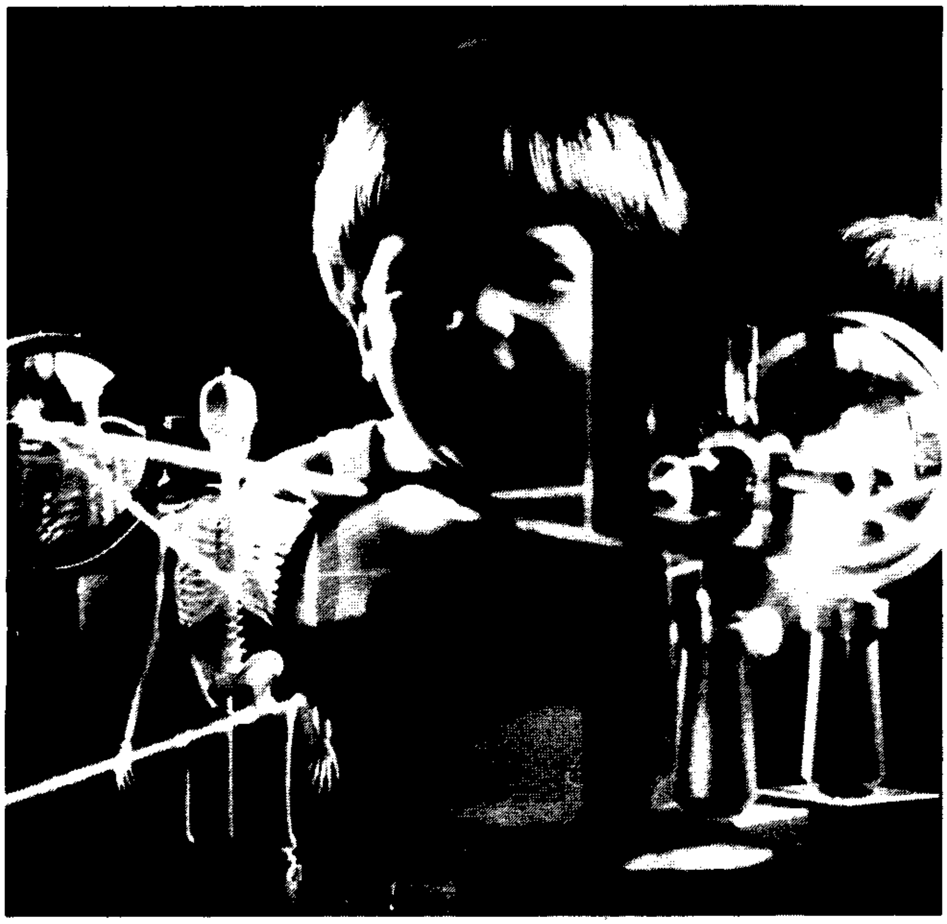

Photo credit: Don Mills, Ontario Science Center

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Learning Outside of School

The children who see colored shadows on the wall in the Exploratorium have not "learned" something you can test. But years later, when a teacher tries to explain light patterns and perception, this experience will be a part of the deep background that will make learning easier.

George W. Tressel, 1988

National concern about the excellence of American schools has sometimes detracted from the recognition that children learn a great deal out of school. The influences of family, friends, the media, and other features of the environment outside of school are profound.

The out-of-school environment offers opportunities to raise students' interest in and awareness of science and mathematics. Table 5-1 presents estimates of the proportion of the school-age population that participate in science-related informal education activities. Such informal activities draw strength from the local community—churches, businesses, voluntary organizations, and their leaders. All are potential agents of change. All are potential filters of the images of science and scientists transmitted by television and other media. These images are often negative—nearly always intimidating—and shape young people's views of science as a career.

Table 5-1 .—Estimated Proportions of Target Populations That Participate in Informal Science and Engineering Education Programs

Occasional viewers of 3-2-1 Contact —50 percent of 4- to 12-year-oids
Regular viewers of 3-2-1 Contact —30-35 percent of 4- to 12-year-olds
Did a science-related activity after viewing 3-2-1 *Contact* —25 percent of 4- to 12-year-olds
Visit a science center or museum --25 percent of school-age students each year
Visit a science center or museum **—50** percent of 4- to 12-year-olds
Visit an aquarium or zoo —90 percent of 4- to 12-year-olds
Take an inservice course at a science center or museum —Less than 1 percent of teachers
Participate in an intervention program —Less than 1 percent of Black and Hispanic students
Participate in an intervention program —Less than 0.1 percent of female students
Enroll in a weekend or summer science enrichment program —0.1 percent of high school graduates

SOURCE: Office of Technology Assessment, 1988

Science centers and museums, for example, can awaken or reinforce interest, without raising the spectre of failure for those who lack confidence in their abilities. (As Frank Oppenheimer, founder of San Francisco's famed Exploratorium, noted, "Nobody flunks a museum.") Intervention programs, aimed especially at enriching the mathematics and science preparation of females, Blacks, Hispanics, and other minorities can rebuild confidence and interest, tapping pools of talent that are now underdeveloped.

THE IMPORTANCE OF FAMILIES

Family circumstances are pivotal influences on career choice. Parents' occupations, attitudes, incomes, residences, and socioeconomic class are all reflected in their children's lives. Much of a child's initial learning about the world, and about reading, speaking, and writing, takes place in the family. Families can give children a head start in preparing for school, in progressing through the educational system, and shaping perceptions of careers.[1]

[1]This is the motivation for the American Association for the Advancement of Science's LINKAGES Project, and particularly for the appeal for minority parental involvement in their children's education, as illustrated by The College Board, *Get Into the Equation:*
(continued on next page)

Although it can be illustrated in many ways, the strong influence of families is indicated by biographic data on winners of the Westinghouse Science Talent Search (WSTS). The WSTS is one of America's oldest high school competitions in the sciences. Between 1942 and 1985, it awarded $2 million to 1,760 young scientists. Its winners have gone on to earn five Nobel Prizes, two Fields Medals, and four MacArthur Foundation ("genius") Awards. Two surveys of previous winners, one conducted in 1961 and another in 1985,[2] suggest that parents, close relatives, or teachers played critical roles in their decisions to become scientists. Male family members were especially important influences (the bulk of the winners were male). For example, in the 1985 survey, 35 percent of winners had fathers who were professional scientists or engineers. Among other influences, 62 percent of the WSTS sample cited a professor or a teacher as playing a major role in their career decision, and 44 percent reported that they became interested in their current professional fields in high school.

Parental involvement in education has always been recognized as important. An innovative mathematics program called Family Math, based at the Lawrence Hall of Science in Berkeley, California, is designed to encourage parents to work

(continued from previous page)
Math and Science, Parents and Children (New York, NY: College Entrance Examination Board, September 1987).

[2]Harold A. Edgerton, ***Science Talent: Its Early Identification and Continuing Development*** (Washington, DC: Science Service, Inc., 1961); and Science Service, Inc., ***Survey of Westinghouse Science Talent Search Winners*** (Washington, DC: Westinghouse Electric Corp., November 1985).

Photo credit: William Mills, Montgomery County Public Schools

Parents are instrumental in shaping their children's attitudes toward education.

with children in solving problems and learning mathematics. Having parents learn something about science and mathematics will, in turn, help children learn.[3]

‘David Holdzkom and Pamela B. Lutz, *Research Within Reach: Science Education; A Research Guided Response to the Concerns of Educators* (Charleston, WV: Appalachia Educational Laboratory, 1984), pp. 192-202; Beth D. Sattes, Educational Services office, Appalachia Educational Laboratory, “Parent Involvement: A Review of the Literature, ” unpublished manuscript, November 1985; Jean Sealey, Appalachia Educational Laboratory}, “Parent Support and Involvement, ” *R&D Interpretation Service Bulletin in Science,* n.d.; Jean Kerr Stenmark et al., *Family Math* (Berkeley, CA: Regents of the University of California, 1986); and The College Board, op. cit,, footnote 1,

THE PUBLIC IMAGE OF SCIENCE

The public image of science and engineering conveyed by television and the other media is ambiguous. On the one hand, science is portrayed as being of great benefit to economic progress and to health. On the other, it is portrayed as a sinister force that bestows power on its adherents and is manipulated by inhumane people.[4] In any case, the process of scientific and technological advance is poorly understood by the public. While the sometimes dismal image of science is one part of the cacophony of discouraging signals that an aspiring young scientist receives (and will certainly cause some students to shun science), evidence suggests that poor images of science are probably not a leading cause of students’ failing to pursue careers in these fields. Academic preparation ultimately is far more important. [5]

Television Images of Science

The public image of science has been studied in a number of separate settings over the years. One study dissected the content of network prime-time dramatic programs between 1973 and 1983. ’ The study found that: 1) some aspect of science and technology appears in 7 of every 10 dramatic television programs; 2) doctors are more positively portrayed than are scientists; and 3) scientists are not as successful in their on-screen occupations as other occupational groups. In fact, for *every* scientist in a major role who fails, two succeed, whereas for every doctor who fails, five succeed, and for every law enforcer who fails, eight succeed. The study also documented a link between these images and viewers’ attitudes and concluded that, while television dramas generally presented positive images of science, the more that viewers see, the more they perceive scientists as odd and peculiar.

Television is a pervasive influence on many students’ lives.[7] It is argued that the effects of television viewing may be strongest for children under 11 years old, because up until that age children are continuing to develop interpretive skills and sophistication in analyzing the content of material. [8] Children’s attitudes toward televised material will be influenced, in other words, by what they have seen and learned of the world. As children grow older, television is critical in the formation of an understanding of social relationships and of the social forces that govern adult life. This window on the adult world may be particularly important in shaping attitudes toward careers and occupations, because adolescents have few social contacts outside their own age group. ”

Television viewing can have positive and negative effects. It can promote racial and sexual stereotypes and perceptions of occupational segregation, or help change attitudes toward the races

‘See, for example, Spencer Weart, “The Physicist as Mad Scientist, ” *Physics Today,* June 1988, pp. 28-37.

[5]The following is based on Robert Fullilove, “Images of Science: Factors Affecting the Choice of Science as a Career, ” OTA contractor report, September 1987.

‘George Gerbner, “Science on Television: How It Affects Public Conceptionsr ” *Issues in Science and Technology,* vol. 3, No. 3, winter 1987, pp. 109-115.

Unpublished data from the mathematics and science assessments of the 1986 National Assessment of Educational Progress indicate that 24 percent of Blacks in grade 11 and 44 percent of Blacks in grade 7 watch **6** hours or more of television daily, compared to 9 percent and **24** percent for the whole populations in grades 7 and 11, respectively (Marion G. Epstein, Educational Testing Service, personal communication, June 1987).

[8]Fullilove, op. cit., footnote 5, pp. 30-36.

“Gary W. Peterson and David F. Peters, “Adolescents’ Construction of Social Reality: The Impact of Television and Peers, ” *Youth and Society,* vol. **15, No.** 1, September 1983, pp. 65-85. Also see Joan Ganz Cooney, “We Need a ‘Sesame Street’ for Big Kids: Television Can Help Our Children Learn Math and Science for the ‘90s, ” *Washington Post,* Sept. 11, 1988, pp. 16-17.

and sexes, depending on the content of programming.[10] Heavy television viewing reduces the time students spend on homework, thus depressing their academic performance. However, television viewing by adolescents is reported to have remained roughly constant over the time that, for example, Scholastic Aptitude Test scores have fallen.”

From a policy perspective, however, even if a link between television portrayals of science and engineering and career aspirations were established, the challenge would be to design television programming that could affect those aspirations positively. Research suggests that it is easier to change attitudes, and therefore aspirations, than to change behaviors.[12]

Students’ Images of Science

In a nationwide study sponsored by the American Association for the Advancement of Science (AAAS) in 1957, high school students were asked to compose short essays describing their impressions of scientists and their work. Margaret Mead and Rhoda Metraux wrote a composite description of science and of scientists from their reading of **35,000** such essays.[13] **They found that:**

> The number of ways in which the image of the scientist contains extremes which appear to be contradictory-too much contact with money or too little; being bald or bearded; confined to work indoors, or traveling far away; talking all the time in a boring way, or never talking at all—all represent deviations from the accepted way of life, from being a normal friendly human being, who lives like other people and gets along with other people.

A 1977 study, 20 years after the work of Mead and Metraux, found that perceptions had changed little. Over 4,000 children from kindergarten to grade five in Montreal, Canada, were asked to draw pictures of what they thought a scientist looked like. The dominant image of scientists found by Mead and Metraux a generation earlier was held by younger students as well. In addition, more elements of the stereotype appear as students advance through the grades.[14]

The Potential of Educational Television

Educational television can be a powerful way to introduce new images and teach students. A prominent example is the Children’s Television Workshop’s **3-2-1 Contact,** funded by the National Science Foundation (NSF) and the Department of Education, and broadcast daily on most public television stations. This show’s target audience is children 8 to 12 years old (although many younger children watch as well). Its aim is to interest these students in science, with particular emphasis on female and minority children. Extensive research has been done on this series. It is estimated that the series is seen in nearly one-quarter of all households with at least one child under 11 years old. Themes in 3-2-1 Contact are echoed in series-related science clubs and a maga-

[10] Fullilove, op. cit., footnote 5.

[11] Mark Fetler, “Television and Reading Achievement: A Secondary Analysis of Data From the *1979-80* National Assessment of Educational Progress, ” presented at the Annual Meeting of the American Educational Research Association, April 1983; and Barbara Ward et al., ***The Relationship of Students’ Academic Achievement to Television Watching, Leisure Time Reading and Homework*** (Washington, DC: National Institute of Education, September 1983). Television viewing has been cited as one of the possible causes for the decline in the Scholastic Aptitude Test scores of America’s college-bound students that occurred in the 1970s. See College Entrance Examination Board, ***On Further Examination: Report of the Advisory Panel on the Scholastic Aptitude Test Score Decline (New*** York, NY: *1977). See* also, U.S. Congress, Congressional Budget Office, ***Educational Achievement: Explanations and Implications of Recent Trends*** (Washington, DC: U.S. Government Printing Office, August 1987), pp. 69-71.

[12] Icek Ajzen and Martin Fishbein, ***Understanding Attitudes and Predicting Social Behavior*** (Englewood Cliffs, NJ: Prentice Hall, 1980); and J. Baggaley, “From Ronald Reagan to Smoking Cessation: The Analysis of Media Impact ,“ New ***Directions in Education and Training Technology,*** B.S. Alloway and G.M. Mills (eds.) (New York, NY: Nicholds Publishing Co., 1985).

[13] Margaret Mead and Rhoda Metraux, “Image of the Scientist Among High-School Students, ” ***Science,*** vol. 126, Aug. 30, 1957, pp. 384-390.

[14] David Wade Chambers, “Stereotypic Images of the Scientist: The Draw-A-Scientist Test,” ***Science Education, vol. 67, No. 2, 1983,*** pp. *255-265,* The stereotypes apparently persist into adulthood, although for many citizens the ambivalence toward science never subsides. Etzioni and Nunn found in a review of national public opinion polls on the attitudes of Americans toward science that most Americans value science for its contribution to the Nation’s high standard of living; similarly, Americans hold generally favorable opinions of scientists and trust their judgment. But images of what a scientist does remain fuzzy, and opinions on science vary significantly by age, education, region, socioeconomic class, and personality type. Amitai Etzioni and Clyde Nunn, “The Public Appreciation of Science in Contemporary America, ” ***Science and Its Public: The Changing Relationship, G.*** Holton and W.A. Blanpied (eds.) (Boston, MA: D. Reidel, 1977), pp. 229-243.

zinc, and it is estimated that one-half of all viewers have done some science-related activity,*'

The impact of a television message may depend more on the characteristics of the viewer, such as his or her age, than on the characteristics of the message. OTA finds no compelling support for the hypothesis that poor images of science by themselves deter students from science and engineering careers. Television is a powerful force, both for good and for bad, but its effect also depends on the prior experience and knowledge of viewers.

“Research Communications, Ltd., “An Exploratory Study of *3-2-1* Contact Viewership, ” National Science Foundation contractor report, June 1987.

The Informal Environments Offered by Science Centers and Science Museums

Science centers and museums aim to bring science alive with exhibits and displays that show scientific phenomena in action, and dedicated staffs determined to spark interest in science. They have important positive effects on students' attitudes toward science and knowledge of physical phenomena.

Science museums were first set up to house and archive the achievements of science and technology through artifacts such as experimental apparatus, machines, field notes, and pictures. As attitudes toward science and science learning have changed, new institutions, called science centers, have sprung up with the primary aim of exciting and educating visitors in science and technology rather than of chronicling its history.[16] Indeed, this development was presaged by science museums. At the turn of the century, the Deutsches Museum in Munich, West Germany, was the first science museum to invite the public to participate in its exhibits, and to introduce cutaways and working models to encourage the public to learn about how things work rather than what they look like. This model was soon copied for use in the new Chicago Museum of Science and Industry in the **1930s.** The preeminent example of a science center is the Exploratorium, in San Francisco, which opened in 1972.

Today, both science museums and science centers use “hands-on” exhibits to illustrate scientific principles through “object-based learning” that schools and school systems often cannot provide because the equipment is too expensive or unavailable.[17] Science centers are also making increasing use of new technology such as computers, video, and videodiscs, both as exhibits in their own right, and as a means of illustrating scientific and technological concepts.

[16]See Sheila Grinell, “Science Centers Come of Age, ” *Issues in Science & Technology*, vol. **4,** No. *3,* spring 1988, pp. 70-7s.

[17]See Michael Templeton, “The Science Museum: Object Lessons in Informal Education, ” ***NSTA Annual 1987,*** Marvin Druger (cd.) (Washington, DC: National Science Teachers Association, forthcoming).

Learning in Science Centers

The learning that occurs in a science center is grounded in the relevance of science to practical daily life, in arousing curiosity, and in allowing people to explore and explain for themselves. Most important, it has no particular aim; no tests are in sight, no goals are prescribed or proscribed, and visitors are free to choose the exhibits that they would like to explore in detail and to ignore the rest. The function of these centers, from the point of view of the education of future scientists and engineers, is not so much to teach scientific concepts, as to interest students and to relate abstract learning in schools to experience of how physical phenomena work and can be altered by humans.

Nationally, there are about 150 centers and museums dedicated to improving public understanding of science and technology; an umbrella organization, the Association of Science-Technology Centers (ASTC), represents most of these centers. A recent survey by ASTC indicated that these 150 centers had about 45 million visitors in 1986, up from 32.5 million in 1979.[18] part of this increase is due to expansion in the number of science centers; over one-half opened after 1960, and 16 percent opened after **1980.** The survey suggests that as many children and young people as adults visit the centers. Probably about 6 million children and young people come on school trips. Interest in science centers is very high. Once largely the preserve of large cities, centers are now being built in many smaller towns, cities, and rural areas.

The people who work in science centers are skilled at helping both adults and children learn about science. Science centers' target audience is the population that is curious but not confident about science. About 100 science centers conduct mathematics and science teacher training programs, funded by school districts, States, or Title 11 funds from the Federal Government. These programs often aim at elementary and middle school teachers, many of whom have almost no grounding in science. About **65,000** teachers par-

Photo credit: Nancy Rodger, Exploratorium

Science centers, which allow children to touch and play with equipment and exhibits, expose them to scientific concepts in an appealing setting.

ticipated in such programs in 1985. Few centers have programs for high school teachers.[19]

Science centers have developed close working relations with school systems in the areas in which they serve, while remaining independent of them. This unique role is often cited as being useful, because it allows the centers to take risks and experiment in science education in ways that school systems find difficult. Nancy Kreinberg, Director of the EQUALS program (see box 5-A) based at the Lawrence Hall of Science in Berkeley, California, has put it this way:

> We are in the schools, but we are not of the schools. We are in the community, but we don't represent one faction of the community. We are seen as representing a lot of different interests, and I think that is an enormous source of strength that every science center has to offer .20

A novel program run by the San Diego School District sends every fifth grader in the city to spend a week at Balboa Park, the city's museum district. A special team of teachers spends the week with the students, exploring both art and science museums. Although designed primarily to assist racial desegregation (the students are formed

[18]These and data cited below are from Association of Science-Technology Centers, "Basic Science Center Data Survey 1988, " unpublished.

[19]Jacalyn Bedworth (cd.), ***Science Teacher Education at Museums: A Resource Guide*** (Washington, DC: Association of Science-Technology Centers, 1985).

[20]Association of Science-Technology Centers, ***Natural Partners: How Science Centers and Community Groups Can Team Up to Increase Science Literacy*** (Washington, DC: July 1987).

Box 5-A.—The EQUALS Program

EQUALS is a program designed to improve the awareness of gender- and race-related issues in mathematics and science education. It. encompasses projects for teachers, counselors, administrators, parents, and school board members to promote the participation of female and minority students in mathematics and computer courses. EQUALS provides curriculum materials, staff development seminars, and family learning opportunities. It is located at the Lawrence Hall of Science (University of California at Berkeley). Since 1977, 14,000 California educators and 9,000 educators from 36 other **States and abroad have participated in EQUALS courses. Sites have been established across the United States.**

Evaluation data from extensive interviews and questionnaires indicate that EQUALS programs increase student enrollment in advanced science and mathematics classes, improve attitudes and interest in related occupations, enhance the professional growth of teachers, and, perhaps most importantly, encourage parent involvement in the schools (the Family Math Program is currently being evaluated with National Science Foundation funds). EQUALS publications, including We *All Count in* Family *Math* and *I'm Madly in Love With Electricity and Other Comments About Their Work by Women in Science and Engineering*, are geared for use in all types of "classrooms," since the emphasis is on hands-on, active problem solving. Materials in Spanish are also available and widely used.

SOURCE: EQUALS Program, Lawrence Hall of Science, University of California at Berkeley.

into heterogeneous groups of 5 to 10 students drawn from different schools, neighborhoods, races, and ethnicities), the program makes use of existing facilities that are neither available to schools nor would readily fit into existing school learning patterns and curricula.[21]

Costs and Benefits

A recent survey indicates that the average science center costs about $1.5 million per year to run, and that most charge between 75 cents and $5 for admission.[22] About 40 percent of expenses incurred by the average center are defrayed by admissions, memberships and other fees, and from sales of souvenirs and food; State and local districts pay, on average, about 28 percent of the costs, while corporations contribute another 10 percent. The average contribution of the Federal Government to ASTC member centers is 6 percent, but the bulk of this goes to the three centers it wholly supports.[23] The remaining centers receive, on average, just 2 percent of their income from Federal sources.

Several Federal programs fund science centers, including the Informal Science Education Program of NSF, the National Endowment for the Humanities, the National Endowment for the Arts, the Institute of Museum Services, and the Department of Education's Secretary's Discretionary Fund. Only the Institute of Museum Services will contribute toward routine operating expenses (and it sets a limit on its contribution of $75,000 per museum per year); the other sources will fund only particular programs and novel educational projects. Indirect Federal support has in the past also come from contributions of equipment and facilities. (Seattle's successful Pacific Science Center, for example, is housed in the United States pavilion built for the 1962 World's Fair, which was given free to the center.)

Evaluations of the effects of science centers on students are limited. The research that has been done indicates that science centers can be effective arenas to demonstrate aspects of the natural world, but have more limited impacts in conveying understanding of the scientific concepts underlying particular exhibits. Visitors often acquire lasting memories of phenomena, such as the formation of a rainbow by the use of a prism, but are less readily able to explain what they have seen or give the proper scientific terms that describe the phenomena. Written information beside exhibits is not often well assimilated. Visitors thus

[21] Judy Diamond, Natural History Museum, San Diego, personal communication, June 1988.

[22] All data in this paragraph are from Association of Science-Technology Centers, op. cit., footnote 18. Note that this database excludes a few science centers and museums that *are* not association members.

[23] These three centers are the Air and Space Museum and the National Museum of American History in Washington, DC (both part of the Smithsonian Institution), and the Bradbury Science Museum, Los Alamos National Laboratory, New Mexico.

build up a good intuition of how things work, based on their experience of phenomena, but little analytical knowledge. Students who are used to figuring things out for themselves, ignoring instructions, often find science centers interesting; the style of learning that science centers employ is radically different from that in formal classrooms where the emphasis is often on obeying rules and memorizing facts.

Learning that takes place in science centers is thus difficult to measure using conventional tests of factual recall (which do not demonstrate "learning" at all), but is clearly important. When families visit and explore exhibits together, parents can often become more confident about science and hence more supportive of any interest that their children might develop.[24] An interesting study of the "Explainer" program at the Exploratorium, in which nonscientifically inclined but enthusiastic high school students explain particular exhibits to visitors, found that, 10 years later, former Explainers were still very interested and confident in science, academic pursuits, and work experiences. (See box 5-B.)

ASTC is working to improve attendance and use of science centers by females and minorities, and is encouraging its members to form links with community and service organizations in the female and minority communities, such as the National Urban League, Girls Clubs of America, and the National Action Council for Minorities in Engineering.[25] Several foundations are helping fund such outreach programs. Minority students, in particular, often need to be encouraged to develop interests in science and engineering, and science centers can help build their confidence in these areas. Several science centers have held highly successful "camp-ins," in which students or teachers spend a whole night learning and playing in a science center,

Informal Learning

Informal education, then, is not just museums and science centers. Informal learning also takes place through reading, watching television, visiting libraries, and participating in clubs. It is this additional informal education, as one NSF staffer puts it—4-H Clubs, Girl's Club of America, Girl Scouts—that warrants". . . a concerted effort to give kids direct hands-on experience. "[26]

[24] Diamond, op. cit., footnote 21.

[25] Association of Science-Technology Centers, op cit., footnote 18. The American Association for the Advancement of Science's Office of Opportunities in Science, through its LINKAGES project, has been the source of many activities spearheaded by the Association of Science-Technology Centers.

[26] George W. Tressel, "The Role of Informal Learning in Science Education, " presented to the Chicago Academy of Sciences, Nov. 14, 1987, p. 11.

INTERVENTION AND ENRICHMENT PROGRAMS

Some kinds of informal education programs are designed to enrich, or even replace, traditional schooling in mathematics and science. One form is the "intervention program, " designed to improve educational opportunities for special groups not often well served in regular classrooms (particularly females and minorities). Other programs for the entire school population allow students to participate, for example, in science experiments in research laboratories, including Federal laboratories, or to enhance their progress through the regular school mathematics and science curriculum. These programs are known as enrichment progams,

Intervention Programs

Ideally, all students would have access in school to high-quality courses in mathematics and science, and their teachers, fellow students, and guidance counselors would be sensitive to the overt and covert racism and sexism that interferes with learning. In 'practice, however, the quality of courses is very uneven, and social attitudes still deter females and minorities from pursuing further science and engineering study. While schools are reforming and improving the situation, change is slow and certainly lagging the demographic changes already occurring. Negative attitudes

Box 5-B.—Learning by Teaching: The Explainer Program at San Franasco's Exploratorium

One of the most powerful ways to learn is by teaching others. The Explainer program at San Francisco's Exploratorium, a science center designed to offer visitors maximum involvement with scientific phenomena and experiments, gives a small group of enthusiastic just this chance. Explainers are located around some of the Exploratorium's exhibits to help visitors by conducting demonstrations, answering questions, and sparking discussion about the concepts that the exhibits convey. The Explainer program is intended both as a service to visitors to the ExpIoratorium, and as a work and educational program to give teenagers an appreciation for science and for learning.

The Exploratorium recruits Explainers from local high schools for their enthusiasm for working with the public, rather than for their interest in science as such. The program deliberately reaches out to students outside the academic and science mainstream; good grades or interest in science are not prerequisites, and in fact are not desired. Potential Explainers have to be friendIy and keen to help visitors, and represent diversity among the population. Over one-half of Explainers are from minority groups; they are equally divided between males and females.

Explainers are hired for a 4-month session, are paid an hourly wage, and receive about sO hours of paid training before and during the job. The program costs the Exploratorium about $250,000 per year (or about $4,000 to $5,000 per Explainer). Most Explainers work only one session.

An evaluation of nearly 900 alumni of the Explainer program was conducted in 1985-86.[1] Former Explainers universally report that their stint at the Exploratorium was a tremendous learning and social experience, as well as a boost to their self-esteem. One of the greatest benefits the Explainers cited was working intensely with a small, diverse group (15 to 20 Explainers work with visitors at any one session), and enjoying professional camaraderie with the Exploratorium staff. Explainers acquired confidence in their ability to learn about subjects they had previously thought inaccessible. They learned to deal with not knowing "all the answers"; they also developed communication and people skills that they later found valuable at college and in the workplace.

Among the comments made by former Explainers were these:

> There would be times when something didn't catch my interest in class, but it did when I learned it here. It was hands on. There was actual proof. It wasn't something read from a textbook.
>
> I learned to tolerate a lot of my own mistakes. . . . You learn to appreciate that you can learn from those that know better. Once at an eye dissection, I got into a conversation with an ophthalmology student. I'd be explaining things but all of a sudden I was learning new stuff by talking to this guy.
>
> It got rid of a stigma for me and let me go and pursue science, which is really what I wanted to do in the first place. I found out that, yeah, you can enjoy science and you're not weird if you do, so why not? Before, I would just keep it to myself, I never told anybody that I read science books before I came here.
>
> That was one of the key things to come out of the Exploratoriuxn experience: becoming a people-oriented person. When you explain something and you see the spark in people's eyes, you are enriching them. You are giving them something, and in return you're getting the feeling that you are enriching their lives.
>
> Part of the reason I liked it a lot was that it gave me the feeling that I was teaching for the first time. 1 was showing people things instead of always having them shown to me.

In sum, the curiosity and desire to learn that Explainers acquired stayed with them in their later lives. ,

Women were much more likely than the men to report that they becae interested in science and engineering and improved their communication skills as a result of the ExpIainer program. Students who were already interested in science and engineering strengthened their confidence; other students gained general self-esteem and were encouraged to go to college.

The Explainer program also helps visitors enjoy themselves and learn. Explainers can particularly help reach their peers—other teenagers who traditionlly have been tough customers for science centers and

[1] Judy Diamond et al., The Exploratorium, "The Exploratorium Explainer Program: The Long-Term Impact on Teenagers of Teaching Science to the Public and a Survey of Science Museum Programs for High School Students, " mimeo, June 19s6. The Explainer program has operated since the opening of the museum in 1%9. For the study, 32 representative alumni were interviewed at length, and a questionnaire was developed on the basis of those interviews and sent out to former Explainers. Other information on Explainers was gathered from interviews with museum visitors and applicants to the Explainer program.

museums to reach. Compared to other age groups, it is believed that comparatively few teenagers attend museums; one study found that many teenagers felt that most museum staff were "patronizing and condescending."

Some other science centers have adopted the Exploratorium model directly and many others have developed other outreach programs for teenagers, including summer classes, mentorships, interpretive guides, and museum staff internships.[2] Many target high-ability, science-oriented students; others are directed to enthusiastic students who are willing to take the job on a volunteer basis.

[2] Ibid.

toward careers in science and engineering conveyed by influences outside schools, such as the media, families, and friends, will not readily be altered.

Against this background, special efforts to intervene must be made in order to attract and encourage females and minorities in science and engineering. Most of these efforts, though few in number, take place out of school during students' free time. Although intervention programs have only been in existence for about 20 years, many successful techniques have been developed for boosting the self-image, enthusiasm, and academic preparation of females and minorities for science and engineering careers. Indeed, some of these techniques (such as stressing the relevance of science understanding to everyday experiences, the use of small groups, and participation in hands-on activities) clearly warrant dissemination to the entire population of students.

The Content and Reach of Intervention Programs

The Office of Opportunities in Science of AAAS collects data on intervention programs, and is an enthusiastic advocate of them.[27] The programs differ from each other considerably in terms of their longevity, bases of operation, sources of support, goals, and quality. Universities, museums, and research centers house the majority of intervention programs, and many serve junior high and high school students. Most effective intervention programs involve learning science by doing, rather than through lectures or reading; working closely with small groups of other students; contact with attentive advisors, mentors, and role models who foster self-confidence and high aspirations; and an emphasis on disseminating information about science and engineering careers. Intervention programs for minority students often reach a high percentage of females as well, both minority and majority. Evaluations suggest that early, sustained intervention can bring minority achievement to the same level as that of white males.

AAAS has examined exemplary intervention programs and has found that they have strong leadership, highly committed and trained teachers, parental support, adequate resources, a sustained focus on careers in science and engineering, clear goals, and continual evaluation. Many combine academic and informal learning, and involve teachers and parents. They often focus on enriching students' experiences in science, rather than in providing remedial treatment for the poor quality experiences that most students have had from formal education; many also stress techniques, such as peer learning, that help students learn how to learn. The intervention programs that work best start early in students' educational careers and have a long-term focus, with the ultimate goal of making successful intervention techniques part of the normal apparatus of the school system.

Most intervention programs require extraordinary staff commitment and support, and are not easy to replicate in other locations. The most talented teachers and leaders can only fully serve a limited number of students, even using technol-

[27] American Association for the Advancement of Science, Office of Opportunities in Science, "Partial List of Precollege Mathematics and Science Programs for Minority and/or Female Students by State," unpublished manuscript, July 1987; and Shirley M. Malcom et al., *Equity and Excellence: Compatible Goals; An Assessment of Programs That Facilitate Increased Access and Achievement of Females and Minorities in K-12 Mathematics and Science Education*, AAAS 84-14 (Washington, DC: American Association for the Advancement of Science, Office of Opportunities in Science, December 1984).

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ogies such as distance learning. Some programs have, however, been replicated. Perhaps the most successful is the Mathematics, Engineering, and Science Achievement (MESA) program based in Berkeley, California. MESA-modeled programs now operate in about 10 other States.

Differences Among Intervention Programs

Intervention programs recognize the different problems that can face females and minorities in science and engineering. Most females, for example, have access to the high school science and mathematics courses that they would need for science and engineering careers; the issue is one of self-image and self-confidence. Some female students mistakenly believe they do not even need to take optional mathematics and science courses for entry to science and engineering majors in college. In addition, during group work in classrooms, male students frequently dominate experimental equipment and computers, leaving female students taking notes and acting as "secretaries. " In all-female intervention programs, each student can fully participate in operating equipment and enjoy the whole experience of making scientific observations. Intervention programs need to focus on encouraging an interest in science and improving student self-confidence in mathematics and science.

Many minorities, on the other hand, do not have access to the necessary mathematics and science courses and are less likely than whites to plan to attend college. While many Blacks and Hispanics are interested and aware of science and engineering careers—historically a route to social mobility—they lack the preparation to enter them. Accordingly, intervention programs need to improve the probability that minorities will be prepared to attend college at all, and then focus on improving their learning of mathematics and science.[28]

Within the minority population, however, there are significant differences that affect the design of intervention programs. Many Mexican-Americans come from poor rural backgrounds and have strong family bonds, but tend to receive little encouragement at home for "book learning. " Cuban-American students often come from well-educated families and do very well in academic coursework. Black students in northern cities may be aware of the rewards of science and engineering, but are often poor and enrolled in poorly funded school systems; their access to necessary courses is limited. Black students in the South, however, are more likely to live in rural areas, and have less knowledge of (and correspondingly, interest in) science and engineering careers. Programs for Black students are needed early in their educational careers, because deficiencies in preparation accumulate at an early age. Asian-Americans are often very well prepared for science and engineering careers, but those from territories of the United States with significant Asian populations, Pacific Islanders such as American Samoa, tend to lack preparation. Boxes 5-C, 5-D, and 5-E illustrate a variety of intervention programs.

Funding Intervention Programs

Despite the effort that has been put into developing intervention programs in the last two decades, and the urgent need for them, there is still only a modest number of programs and, collectively, they reach only a small proportion of their target populations. The leaders of several major intervention programs meet as the National Association of Precollege Directors (NAPD), which estimates that intervention programs reach 40,000 minority students annually (or less than 1 percent of the total minority student population). But 25,000 participants in NAPD programs have graduated from high school, over half to major in science or engineering.[29] Expansion is limited both by the shortage of individuals prepared to commit the time and energy necessary to initiate these programs and by lack of funding. A local base of support seems to be an essential ingredient of success.

Some intervention programs owe their origins to Federal funding. Many today are supported by States, foundations, and industry. Federal funds,

[28]For discussion of the more general goal, see Gloria De Necochea, "Expanding the Hispanic College Pool: Pre-College Strategies That Work, " *Change,* May/June 1988, pp. 61-65.

[29]Joel B. Aranson, "NSF Initiatives—A Minority View, " ***Opportunities for Strategic Investment in K-12 Science Education: Options for the National Science Foundation,*** Michael S. Knapp et al. (eds.) (Menlo Park, CA: SRI International, June 1987), vol. 2, p. 112.

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Box 5-C.-National Council of La Raza

The National Council of La Raza is headquartered in Washington, DC, and has program offices in Phoenix, Edinburg (Texas), and Los Angeles. Over the last several years, the organization has developed and demonstrated five innovative community-based approaches to improve the educational status of Hispanics. Three of the five projects cater to precollege students in special "at-risk" populations; the other two focus on the needs of parents and teachers. Original support was provided by the American Can Co. Foundation, and further funding has come from AT&T and Carnegie Corp. grants. Projects in Kansas City, Phoenix, and Houston recently received grants from Time, Inc. and the Xerox Corp. Projects in Several other cities have community and foundation funding.

The council's educational programs supplement school offerings, their rationale being that enrichment programs improve the educational experience of Hispanic children more than do remedial programs that repeat school lessons. The council serves as a national advocacy organization to encourage systemic reforms in teacher training, continuing education, and effective school practices. Project coordinators are confident that much change can be initiated through community-generated local projects. The five community-based approaches are the Academia del Pueblo, Project Success, Project Second Chance, Parents as Partners, and the Teacher Support Network.

The problems of early academic failure and the large number of Hispanic children who must repeat grades are addressed by the Academia del Pueblo, which provides after-school and summer "academies" for elementary school-aged children. These efforts help students meet and exceed grade promotion requirements. Project Success provides career and academic counseling to help junior high students raise their expectations and to support their eventual progress to h@ school graduation. Project Second Chance targets dropouts using volunteer mentors and tutors. The Parents as Partners program was designed to reinforce the concept that parents are effective teachers, antiqularly infl that is in Hispanic communities. This project trains and assists parents to encourage and be tutors to their children. The Teacher Support Network brings together community resources to train and support both Hispanic and non-Hispanic teachers who work with Hispanic children.

The council assists demonstration sites with the necessining and' arid technicaltance to implement the models, and monitors and evaluates the projects. The council also transfers lessons arising from demonstration projects. A necessary component of any council program is the development of participants' Spanish language skills, either as an integral component of the curriculum or as a second language. In addition, the council is assisting the Association of Science-Technology Centers to identify Hispanic community-based organizations with a mathematics and science education focus to encourage their participation in science centers and museums.

however, play an important base role. Since many intervention programs piggy-back on existing facilities in schools, science centers, research laboratories, and universities, the programs are relatively inexpensive. They are labor- not capital-intensive, and many have budgets of several hundred dollars per student. (College-level programs tend to be more expensive, sometimes around several thousand dollars per student, although this sum might include tuition and scholarship support.)

Intervention programs were one outgrowth of the civil rights movement of the 1960s. Federal law eventually was extended to address many forms of discrimination, by race, sex, handicap, and age; intervention programs began to attract Federal funding as a way of breaking down some of the barriers to full participation of these groups in science and engineering. One source of the funding was the Women's Educational Equity Act of 1974, administered by the Department of Education. Another was grants for State programs, funded under Title IX of the Higher Education Amendments of 1974. Federal funds have often acted, and been most effective, as seed funding to initiate intervention programs; if successful, such programs have sometimes then been funded by States and industry in their community.

By contrast, NSF historically has not emphasized either intervention programs or other ways

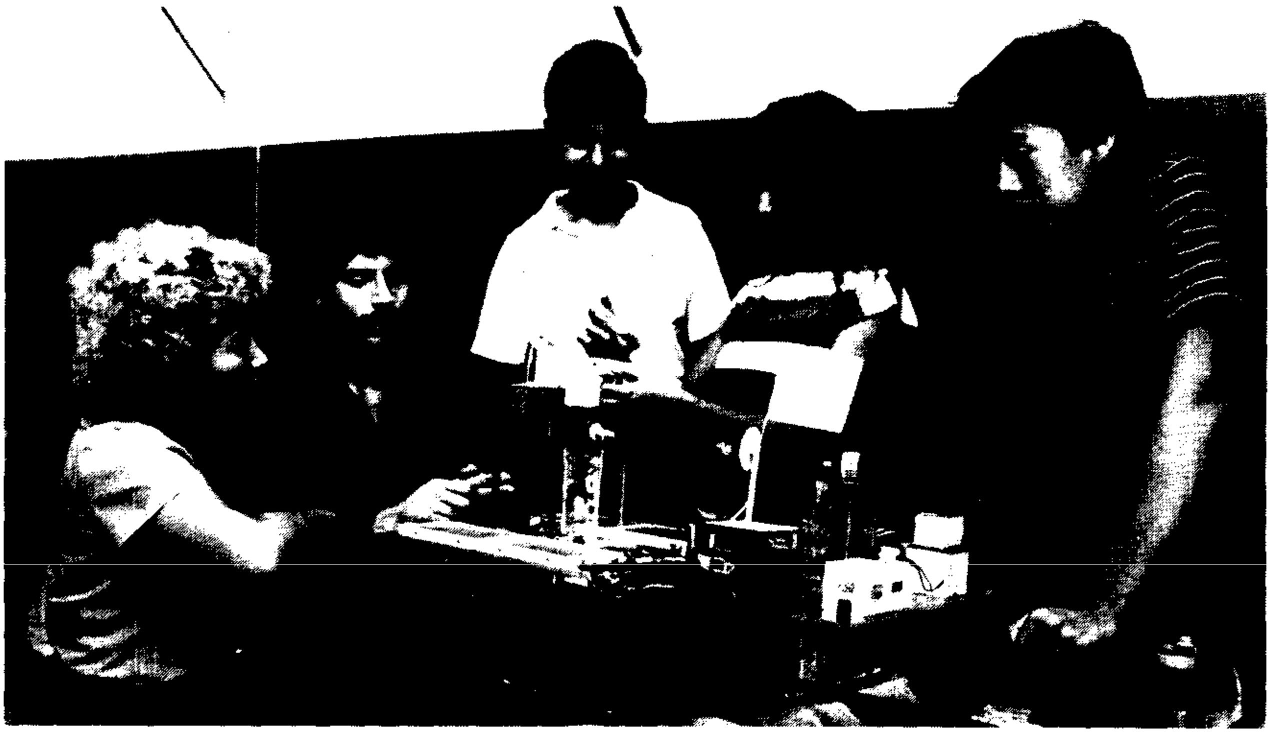

Photo credit: William Mi//s, Montgomery County Pub//c Schoo/s

Intervention programs, like the summer research programs for Hispanic students shown here, give students a chance to work together on real research projects.

Box 5-D.—American Indian Science and Engineering Society

The American Indian Science and Engineering Society (AISES) is a nonpolitical national organization of American Indian scientists and engineers. The society's primary purpose is to expand American Indian participation in science and engineering careers and to promote technical awareness among other Indians. Since it was founded in 1977, AISES has grown to represent 61 tribes in 36 States and Canada. Projects are designed to encourage academic excellence at all education levels. The precollege programs coordinate teacher training seminars and summer enrichment programs, provide materials (including computers), introduce role models through science fairs and camps, sponsor competitions, coordinate student chapters, and publish newsletters and videotapes. Collegiate programs include mentorships, internships, and workshops. The Collegiate Chapter Program includes an annual 2-day conference for leadership training and focuses on providing scholarship information and peer support at 35 institutions. Professional programs are also available for Indian scientists and engineers.

Funding sources are public and private, including the National Science Foundation, the Department of Education Fund for the Improvement of Post-Secondary Education, the National Aeronautics and Space Administration, Hewlett Packard, and Hughes Aircraft. The society also earns some income from the publication of Winds *of Change,* a quarterly magazine designed to disseminate information on educational opportunities and AISES activities, and to promote involvement of Indian and non-Indian participants in Indian concerns. To benefit from AISES programs, schools and agencies must affiliate with the society. The society's annual conference brings together Indian students, the affiliates, and non-lndian professionals from the public and private sectors.

SOURCE: American Indian Science and Engineering Society, Boulder, CO.

Box 5-E.—Philadelphia Regional Introduction for Minorities to Engineering

Founded in 1973, Philadelphia Regional Introduction for Minorities to Engineering (PRIME) is a non-profit corporation devoted to creating opportunities for minorities in engineering, pharmacy, and other mathematics- and science-based professions. PRIME was incorporated in 1975 as a partnership of Philadelphia area businesses, government agencies, colleges and universities, professional associations, and parent groups, and caters to junior and senior high school students in the Philadelphia, southern New Jersey, and Greater Delaware Valley region. The program is funded by member organizations—including 32 companies, 6 State and local agencies, and every major local college and university in the region. Each of these organization's active interest in improving the number and quality of young minority engineers has helped ensure the program's success. Original support came from the Sloan Foundation, but institutional support has been steady. The program's success is evident in its longevity, continued expansion, and the high percentage of the program's students who graduate college and enter their chosen professions.

PRIME's identification of students interested in mathematics and science subjects begins in the seventh grade. Early intervention, it is believed, contributes to the program's success. "Capable" minority students (as defined by test scores, teacher recommendations, and scholastic achievement) are provided with specialized supplementary activities, counseling, and monitoring throughout the remainder of their academic years. Hands-on projects are emphasized in classes, and industry and government representatives visit classrooms monthly, providing role models.

Students also interact with member agencies through workshops and field trips. During the summer, PRIME offers competitive university-based residential training programs (PRIME Universities Program), sponsored originally by a grant of $50,000 from General Electric. While in college and after graduation, students receive job referral and placement assistance. Guidance is continuous; students receive advice on everything from how to cope with precollege coursework to selecting an appropriate university and obtaining financial aid. Enrollment in the summer program is 80 percent Black and 5 percent Hispanic; the academic year program includes only Black students. Both programs have equal numbers of males and females.

PRIME serves more than 3,000 students each year. Recent statistics show that 92 percent of PRIME high school graduates college, and 73 percent of those enter technical and/or engineering programs. Eighty-five percent earn baccalaureate degrees.

SOURCE: PRIME, Inc., Philadelphia.

of improving the "career chances" of females and minorities in science and engineering. NSF programs that have had some success include: the Women in Science program (1974-76, 1979-81); the Resource Centers for Science and Engineering program, aimed at minorities (1978-81); and the Research Apprenticeship for Minority High School Students (1980-82). None of these programs was reestablished when NSF's Science and Engineering Education (SEE) Directorate was reborn in 1983, although the Research Apprenticeship for Minority High School Students and the Resource Centers program have recently been resurrected. With these two exceptions, none of SEE's current programs directly address "underrepresented" groups. Programs for these groups have not been well funded through other NSF efforts, although some receive funding (for example, through Science and Mathematics Education Networks, and Teacher Enhancement). SEE encourages the submission of proposals for projects to address underrepresented groups.[30]

Funding sources for intervention programs have varied according to the program's target populations. Mission agencies have set different priorities. NSF and the Department of Education have established intervention programs for females; foundations, the military, and other Federal agencies (such as the Department of Health and Human Services, the National Aeronautics and Space Administration, and the Department of Energy)

[30] While the National Science Foundation proposed two specific minority programs for fiscal year 1988 and is planning more, their approach has been criticized as insufficient for the magnitude of the problem. See ibid., pp. 111-112.

have tended to fund programs for minorities. Overall, however, there have been few sustained funders of "women in science" programs. Much targeted human resource support is done *institutionally* to categories such as historically Black colleges and universities. But this support, too, seems modest relative to the number of lives they are supposed to change and careers they claim to launch."

Initially, intervention programs were based outside schools. Schools, in fact, have often been viewed by advocates of intervention programs as part of the problem rather than part of the solution. But in recent years, schools have increasingly begun to work with intervention programs such as the METRO Achievement Program in Chicago. Interventions such as the Ford Foundation's Urban Mathematics Collaborative work directly with mathematics teachers outside the school systems in the cities that the program serves; this frees teachers from the organizational and attitudinal constraints that such systems engender. It is important that intervention programs complement efforts to improve the formal education system.

[31]OTA research found that benefactors scale down their gifts to fit their expectations of success when historically Black institutions are involved. Foundations that give $1 million to an Ivy League school will give an institution with primarily minority enrollment $100,000 for the same activity. Also see Tom Junod, "Are Black Colleges Necessary?" ***Atlanta,*** vol. 27, October 1987, pp. 78-81.

Enrichment Programs

Many programs are designed to enrich or speed the progress of talented individuals through science and mathematics courses. Several Federal laboratories, most prominently those of the Department of Energy, provide summer research participation programs that allow students to experience science in the flesh by active participation in real research. While there is no conclusive evidence that such programs change students' career destinations, they have a potent effect in confirming student inclinations that research can be fun. Several universities operate summer courses in mathematics and science for talented individuals. The best known are the Center for the Advancement of Talented Youth at The Johns Hopkins University and the Talent Identification Program at Duke University. (See box 5-F.)

CONCLUSIONS

It is clear that intervention and enrichment programs are a valuable supplement to formal education. The expectations and attitudes of parents and teachers; differential access to courses, instrumentation, and educational technologies; and lack of information or mentoring by role models lead many female and minority students away from science and engineering careers. The magnitude and complexity of the problem requires a large and continuing effort.

Experience with intervention programs has provided considerable knowledge on elements of successful models to replicate in future programs. The reasons why intervention programs have failed, not surprisingly, have tended not to be well documented.

When provided with early, excellent, and sustained instruction and guidance, the achievement levels of females and minorities in science and engineering can match those of any other student. In other words, there are no inherent barriers to participation. The Federal role in intervention programs is to encourage new starts, possibly to expand funding, and to provide networks for the elements of successful programs to be disseminated and shared. Some programs should be based in schools, while others should not. Tailoring each to the needs of specific populations, circumstances, and problems, is, in this domain as well as in many other areas of education, the key to success.

Box 5-F.—Duke University Talent Identification Program

The Duke Talent Identification Program (TIP) was founded in 1980 by Robert Sawyer, Associate Professor of Education at Duke University, to identify academically talented adolescents and accelerate their education.[1] The program provides them with information about their abilities and academic options, and sponsors special educational programs for them. The "Talent Search" operates in 16 States, but the program is open to all qualified students nationwide.

TIP operates four educational programs for talented adolescents: a Summer Residential Program, a Precollege Program (also residential and held in the summer, but offering college credit for coursework), a By-Mail Program, and a Commuter Program. The programs are largely financed by student fees, but financial aid is readily available. Students must take the Scholastic Aptitude Test (SAT) in the seventh grade to qualify for admission. Twelve percent of the students that TIP identified in 1986 scored higher than the average college-bound senior in mathematics, while 15 percent scored higher than average in verbal skills. A variety of academic programs are then offered to the students based on the test scores.

An average class profile is as follows: for the 3-week summer biology course, students range from 7th to 10th grade, have previously passed algebra II, and have SAT scores of 1,000 or higher (this score is generally the minimum for the seventh graders; the scores are progressively higher as the students get older). The student body averages 50 percent female, 23 percent Asian, and 18 percent other racial and ethnic minorities. Most of the students have already skipped at least one grade in their formal schooling. Evaluation consists of the College Board Advanced Placement topical essay examination and an appropriate achievement test, in addition to laboratory work and research projects. The students are not graded (except in college courses), but they are given information on their results to let them know how they are doing. The programs place emphasis on science writing and using challenging textbooks. The program has collected some followup data; it has found that 20 percent of the students go back to regular courses during the subsequent school year, and 35 percent to advanced placement courses.

TIP maintains an automated database that tracks the 140,000-plus participants, and research is in progress on the post-secondary activities of these youngsters. The program publishes a quarterly newsletter, *Insights*, that is distributed nationwide. *Insights* features reports on TIP activities, summaries of significant research on education, special program descriptions, announcements of academic competitions, book reviews, teacher and student resources, and articles on college and career options.

[1]Funding was initiated with a $280,000, 5-year grant from the Duke University Endowment; 91 percent of the program budget at present is provided by student fees, with the remaining 9 percent funded through gifts, grants, and the sale of materials to outside parties.