Paths to a solution

How local, state and national initiatives are addressing the need for improved financial benefits, better training and greater recognition for science teachers, and for programs to attract more science students.

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The crisis in physics education—and in math and science education in general—has two primary features: the severe shortage of qualified teachers and the small fraction of high-school students choosing to take physics and other elective science and math courses. Both of these problems have contributed to the science illiteracy that is now the focus of national attention. As the American public, scientists, politicians and other citizens have become aware of the significance of the crisis, they have put forward many new ideas. State and local governments, teachers' unions, university professors and leaders of business and industry have gone beyond the stereotypical and Pavlovian responses that have often blocked change in the past.

The result is a burgeoning of new Federal, state and local programs throughout the country. For reasons elaborated in other articles in this issue, these programs will be successful in ending the shortage of science and math teachers only if they include:

- ▶ improvement in financial benefits for science teachers
- ▶ reexamination of state certification requirements
- ▶ appropriate preservice and in-service training

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Science students mapping the field lines of a bar magnet.

▶ methods of recognizing effective teachers.

Solving this problem will help solve the other major problem—that of low science enrollments—for there is no doubt that good teachers attract students to physics and other science classes. However, there are additional ways to increase science enrollments, including

▶ providing adequate equipment and outside support to help teachers increase the excitement and interest of science classes

▶ raising high-school graduation requirements

▶ raising college entrance requirements

▶ establishing programs to attract female and minority students.

In this article we describe some of the recent activities aimed at improving science education to stimulate readers to support new initiatives and put forth their own ideas.[1] We will begin with a discussion of state and local initiatives, and proceed to a summary of recent Federal proposals and actions.

Attracting more science teachers

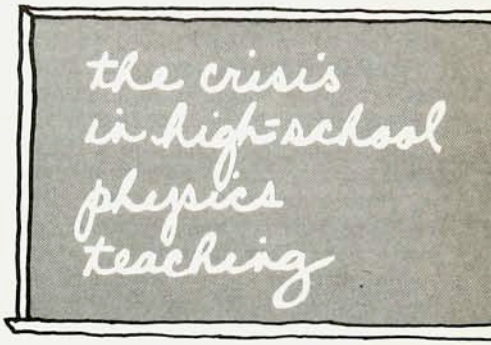
Among the new programs aimed at attracting young people into careers as science and math teachers are those designed to improve financial benefits for teachers. Several states have recently begun programs of forgivable loans for students preparing to become teachers in subjects with critical shortages, such as math and science. These loans are forgiven after several years of teaching. In 1982, the Kentucky state legislature put $600 000 into such a program. Alabama has also begun a loan program, and several other states have similar plans. The state programs will augment the effect of similar loan programs at the Federal level.

Another experiment to address the teacher shortage is to offer higher salaries to those who teach in areas of critical shortages. Although teachers' unions have been strongly opposed to differential salaries, the concept has been tried in several nonunion school districts such as Houston and Oklahoma City, with notable success in attracting new teachers. The controversy over differential salaries has lead to a variety of alternative approaches. Many school districts offer 11- or 12-month contracts to math and science teachers who are willing to devote summer months to teaching or developing curriculum materials. The Garland Independent School District in Texas has approved an Academic Coach Program that allows outstanding teachers to receive supplemental pay for additional teaching activities; this is similar to the supplemental pay programs for athletic coaches. A new program in North Carolina will pay one science teacher and one math teacher in each high school for six weeks during the summer to work at improving instruction.

A cost-effective approach to increasing the annual salaries of science teachers is to provide them with summer employment in industry where they can use their knowledge while learning more about practical applications of science. Several states have proposed tax incentives for companies that hire science teachers. In Minnesota, part of the governor's economic development plan includes a program that offers $5000 to science teachers selected for summer work in industry.

Last June, the University of Massachusetts at Amherst brought together scientists, science educators, representatives of industry and representatives of school districts in the Boston area to develop a special program for college graduates who majored in science or math. During a 14-month period, the graduates spend one semester teaching in a Boston high school, four months working 20 hours per week in industry, and complete sufficient course work to receive high-school teaching certification and a master of education degree. The new teachers are then committed to teach three years in the Boston public schools, during which time they are guaranteed summer employment in industry. Superintendents from the cooperating public school districts and scientists from the cooperating businesses and industries are involved in the admission of students to the program.

Simplifying certification. Because unnecessarily complex and time-consuming certification requirements may discourage students from choosing careers in science teaching, a number of states are reexamining their requirements. The Virginia Board of Education has agreed to give two-year provisional high-school certification to liberal arts and science majors who are untrained in teaching methods. During the two-year period, teachers are required to take nine credit hours in teaching-methods courses and be observed and aided by experienced teachers. At the end of the two years, the teachers are to be evaluated and either receive certification or leave teaching. Other states are considering similar programs.



The simplification of state certification requirements could open up another source of high-school physics teachers. Professional scientists and engineers might consider midcareer changes and become high-school teachers, particularly if they are eligible for early retirement or voluntary severance plans. This fall, the Harvard Graduate School of Education is starting "The Midcareer Math and Science Program" to provide teacher training for mid- to late-career mathematicians and scientists now working in industry. The program features extensive student teaching and will enable students to meet Massachusetts certification requirements.

Many late-career and retired physicists and engineers, who do not wish to teach full-time, may be willing to do so part-time or work with high-school teachers in curriculum development or laboratory improvement. The American Physical Society's Committee on Education and Committee on Opportunities in Physics are working together to identify people who will participate in a pilot project of this type. Paul Horwitz describes this in his letter on page 110.

The current economy and engineering job shortages have made physics teaching positions more attractive to recent engineering graduates. Texas A&M University recently instituted a program in which new engineering graduates take courses during the summer following their graduation and meet the certification requirements (except for student teaching) to teach physics. The first group of engineers will be available to accept teaching positions on emergency certificates this month.

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Inservice training. Another aspect of the current crisis is that the science and math teachers who leave teaching for higher paying industrial jobs are often replaced with teachers who are unqualified to teach those subjects. The table on page 47 shows the magnitude of the problem. It is of critical importance to science programs in the schools that they retain their good teachers, and there is a desperate need to retrain teachers who have been switched into physics, chemistry and math from other subjects.

Many of the most experienced and best physics teachers state that the NSF summer institutes held in the 1960s and early 1970s provided the most important positive influence on their teaching careers. Summer institutes do many things for physics teachers: They review the basic subject matter, present new teaching techniques and ideas for labs and demonstrations, and give teachers a sense of being part of the physics community. There are many initiatives underway to begin summer institutes again, particularly as more Federal money becomes available. Several programs, including a summer institute for science teachers at Fermilab and a workshop on physics demonstrations at Oakland University in Michigan, were held this summer. To write guidelines for new programs, the APS Committee on Education is planning a conference that will bring together many of the people who organized successful teacher institutes in the past. Thus, the new programs will be based on the solid foundation of past experience, and many of the pitfalls will be avoided.

Business and industry are participating in initiatives aimed at retaining and retraining science teachers. Several corporations in New Jersey are helping to support a science education consortium—organized by a local physics teacher—by contributing money for special programs for both science teachers and students. Other corporations are participating in "adopt-a-school" programs in which each company works with a different school by sending employees to help teach math and science, by providing technical assistance, by helping to buy equipment and by inviting teachers and students to see science and technology at work at their plant sites. Adopt-a-school programs are operating in Birmingham, Alabama, and Indianapolis, Indiana.

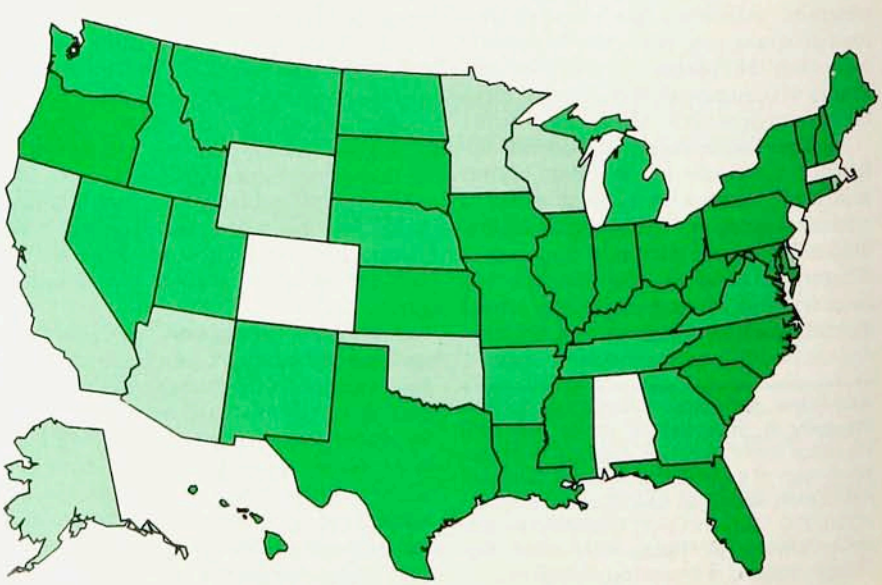
In the absence of formal teacher workshops or institutes, college and university faculties can play a major role in their local areas in retraining science teachers and encouraging them to stay on. Informal programs that bring groups of physics teachers together to discuss problems of general concern help overcome feelings of isolation and frustration. Saturday-morning programs in which college and high-school teachers share ideas about physics demonstrations or discuss scientific topics of current interest can be coupled with guided tours of local research facilities. Visits to local schools by college faculty to help assess laboratory equipment and help plan the purchase of new equipment can also be valuable. A joint APS–AAPT committee is studying successful college and high-school programs and is helping other colleges and universities to initiate new programs.

Good laboratory science teaching is a time-consuming job that requires great devotion. Yet there is no established system to give good teachers any reward beyond the intrinsic pleasure they get from seeing students excited about science. A number of new programs to recognize high-quality teachers have been proposed, including programs based on the concept of the "master teacher." Such a program would designate the very best teachers as master teachers, and give them extra salary and extended contracts for supervising and training other teachers. A master teacher system that involves both teachers and parents in the evaluation process is currently being tried in Los Angeles. Last year, Tennessee considered a system of incentive pay, based on a four-stage professional path: apprentice, professional, senior and master teacher. Although the state legislature did not approve this system due to strong opposition from the teachers' union, the governor continues to support it, and the legislature may reconsider it soon. The recent report[2] of the National Commission on Excellence in Education calls for incentive pay systems such as the master teacher program. At the national level, presidential initiatives to honor outstanding science and math teachers are underway.

Attracting more students

Students must have more and better opportunities to learn science while in school. The National Commission on Excellence in Education named science to be one of the five basic subjects and recommended that all students take at least three years of it in high school. Other national groups urge that more science be taught in the elementary schools and that science specialists be assigned to each school. Many states and school districts have increased their high-school science and math graduation requirements, from one year of each to two at the minimum.

Another way to encourage students to take more high-school math and science courses is to raise college and university entrance requirements, which several states are doing. The Board of Regents of the University of Wisconsin plans to write to parents recommending that their eighth-grade children take three years of math and three years of science to prepare for probable changes in entrance requirements. Oregon has made plans to increase the entrance requirement at its state universities to three years of



Shortages of high-school physics teachers, 1983. Darker shading indicates greater shortage. The lightest shading covers states with approximate balance between supply and demand. Unshaded states did not respond to the survey. No state reported a surplus of physics teachers. (Based on a survey by Trevor G. Howe of Iowa State University and Jack A. Gerlovich of the Iowa Department of Public Instruction.)

Science teachers working with batteries and light bulbs at a workshop. (Photograph by Pete Lohstreter, courtesy of The Science Teacher.)

mathematics by 1986. The California state universities are now informing school districts about what students will be expected to know when they start college.

Women and minorities. Efforts to increase science and technology literacy must be broadened to bring more females and minorities into the pool of students who are attracted to science. Some students need extra counseling and encouragement if they are to contemplate careers in nontraditional fields. In response to this need, both the APS Committee on Minorities and the APS Committee on the Status of Women in Physics have been active in supplying information and incentives to students. The APS Corporate Minority Scholarship Program awards college scholarships sponsored by industry to outstanding black, Hispanic and Native American students majoring in physics. The program also offers encouragement and advice through a mentorship system. The Committee on the Status of Women in Physics recently produced an excellent physics career booklet[3] aimed at girls in grades 7 to 10. The committee also compiled a packet of materials[4] for junior- and senior-high-school guidance counselors, containing information on careers in science and technology and suggestions for encouraging girls to take additional math and science courses and to consider nontraditional careers.

One might expect it to be easy to attract students to science because most children begin elementary school with a strong, natural interest in the subject. By the time they enter junior high school, however, many have lost their positive attitudes toward science, and in high school, the majority of students take only one year of science to meet the minimum graduation requirement. Any comprehensive solution to the problem of science literacy, therefore, must include a plan to improve elementary and junior-high-school science programs and thus break the chain of negative attitudes.

One step toward such a plan was suggested by a group of about 30 scientists and science educators who met last March under the auspices of a task force of the Commission on Precollege Education in Mathematics, Science, and Technology. The group agreed that new science curricula are needed for grades 7 to 10, and recommended courses that integrate science and technology and emphasize the development of quantitative skills so that students can understand the significance of science for themselves and their community. Local industry and community scientists could play important parts in the development of such curricula.

Even if school science programs become more interesting to students, much of the excitement of science will continue to come from supplementary activities or from outside the schools. For some students, competing in science fairs or visiting science museums supplies this stimulation. Others attend special science programs at local universities or national laboratories. Caltech and City College, New York, have run successful Saturday programs throughout the school year. Summer science programs for high-school students used to be sponsored by NSF and perhaps will be reinstated. Some retired physicists have provided special science experiences for students. The "Adventure in Science Program," organized by Ralph Nash in the basement of his Gaithersburg, Maryland, house, is a noteworthy example.

Federal initiatives

Although the actions on the part of state and local districts have been significant, the crisis in science education cannot be solved without Federal support. Over the last year, the US Congress has increasingly shown great interest in the problems in science and mathematics education.[5] The session of Congress that ended 1 December 1982 saw 17 bills introduced addressing the crisis. Many of these bills were reintroduced in the current session. The House of Representatives has passed one, HR 1310, providing $425 million in FY 1984, which begins 1 October 1983. Most of the bills introduced in Congress address problems at

Unqualified teachers

Census region	Fraction of teachers newly hired (%) 1980–1981	1981–1982
Pacific states	75	84
Mountain states	44	43
West north-central states	26	43
West south-central states	63	63
East north-central states	23	32
East south-central states	43	40
Northeastern states	11	9
Middle Atlantic states	40	46
South Atlantic states	48	50
Nationwide	45	50

Figures show the fraction of new science and math teachers not trained to teach those subjects.

Calculations. This student is solving ideal-gas-law problems on a chapter test. (Photograph by Jerome Berkowitz.)

the precollege level—unqualified science and mathematics teachers, shortages of students entering teacher education programs, lack of materials and supplies, and the general problems of support of precollege science and mathematics education.

There are great differences of opinion as to where to aim support for science education. The Administration, true to its conservative principles, wants to limit seriously Federal support and to provide any money largely through block grants or other programs under strict local control. Thus, for FY 1984, the Administration has proposed a modest program involving grant allotments totalling $39 million for the National Science Foundation and $50 million for the Department of Education. The National Science Foundation authorization bill, HR 2066, added the Administration's request of $39 million to the $425 million of HR 1310. The net result from the bills introduced in the House of Representatives is $169 million for the National Science Foundation, with the balance of $295 million for block grants and other programs run by the Department of Education.

In the Senate, however, the situation has been somewhat different. Strong lobbies that want to reestablish general Federal aid to education are trying to use the crisis in science and mathematics education to further that cause. They have produced bills that will simply spread the money by formulas and entitlements rather than by merit or demonstrated need. It is unfortunate that much of HR 1310, as well as most of what is coming out of the Senate for science education, has been politically tainted in this way. Large amounts of money—approximately one-half billion dollars per year—may be spent for several years without regard to the specific parts of the country or to the particular problem areas that need help. The helter-skelter approach reinforces the notion that the Federal government cannot solve educational problems, and helps justify the complaints of the critics. After all the spending is done, the critics will say, "Well, we spent all the money, but look, it didn't do any good."

What is especially disturbing is that there exists in the Federal bureaucracy an agency that has primary responsibility for science education at all levels, including the precollege level, but is not being used adequately—the National Science Foundation. (See the figure on the opposite page.) In our opinion, if half of the funds contained in the House and Senate bills were allocated through NSF programs, they would do far more to resolve the problems in science education than will all the various block grants and entitlement funds disseminated by the Department of Education. Furthermore, NSF expenditures would maintain communication among scientists, science educators in colleges and universities, and the science teachers themselves. These connections are essential if we are to bring current and accurate scientific knowledge into the schools. Unfortunately, all of the various science education bills offer poor substitutes for well-targeted NSF programs that would improve course content, upgrade the teachers, provide needed equipment and supplies, and generally address the most crucial problems.

The National Science Foundation is spending what remains of its FY 1983 precollege science and mathematics education budget on curriculum development and teacher incentives. The teacher incentives are designed to improve the image and status of science and math teachers. The incentives include Presidential Awards for Science and Mathematics Teaching Excellence and Teacher Honors Workshops. The Presidential Awards give highly visible recognition to approximately 100 outstanding teachers, who are selected nationally with at least one teacher from each state. Those selected receive certificates of excellence and awards of $5000 to supplement other resources for improving their schools' science or mathematics program. The National Science Teachers Association assists with the identification, nomination and selection procedures for this program. It is hoped that the activities initiated in 1983 will continue with an increased budget allotment in FY 1984.

While the funds that will go out in block grants and as entitlements administered by the Department of Education may not be spent as efficiently as the NSF funds, some of that money will do some good. It is encouraging that soon there will be Federal funds to improve science and mathematics education. The very fact that Congress and the Administration recognize that a crisis in science education exists and must be addressed to ensure the technological future of our nation is a positive step toward Federal solutions.

What physicists can do

Physicists and physics educators can play an important role in drawing national and state attention to the problems of science education. Physicists have organized statewide conferences that induce communication among state government, business and industry, institutions of higher education and the secondary schools, and lead to changes in state regulations and to the formation of ongoing joint committees. Such conferences have been held successfully in Indiana, Texas, Wisconsin and Maryland.

The Indiana meeting, held last fall, serves as a good example of the impact that a conference can have. This one-day statewide conference was orga-

nized at Indiana University in Bloomington by five faculty members representing the physics, chemistry, math, and science and math education departments. The organizers aimed to improve math and science education in the schools of Indiana by implementing a three-stage program: the broad dissemination of a position paper, the conference itself with media coverage, and the wide circulation of a final conference report. The initial position paper, together with an invitation to the conference, went out to more than 1000 people, including all Indiana legislators, personnel at the Department of Public Instruction, members of statewide lobby groups, leaders of business and industry, and school administrators. The paper reviewed the relationship of science and mathematics education to Indiana's economy and discussed the severe shortage of science and math teachers. It also addressed the weak science and math high-school graduation requirements mandated by the state, and it listed 41 recommendations for improvements to be carried out by the state government, the school systems, colleges and universities, and the private sector.

Partly as a result of the conference, which over 300 people attended, Indiana raised its high-school graduation requirements from one year each of science and math, to two. During the last session of the Indiana Legislature, two bills dealing with science and mathematics education passed with the help of the Indiana State Teachers Association. One set up a program of forgivable loans for students who are studying to become teachers in subjects with critical shortages, and the second set up a program of tax credits for companies employing teachers of those subjects during the summers. Since the conference, the governor has made improved science and math education part of his plan for the economic development of the state. Last spring, the science consultant of the Department of Public Instruction called a statewide meeting of science educators to reexamine the state's certification requirements for science teachers in an effort to encourage more students to choose careers in science teaching. Although some of these activities might have occurred in the absence of the conference, many were stimulated directly by the position paper, the conference and the conference report.

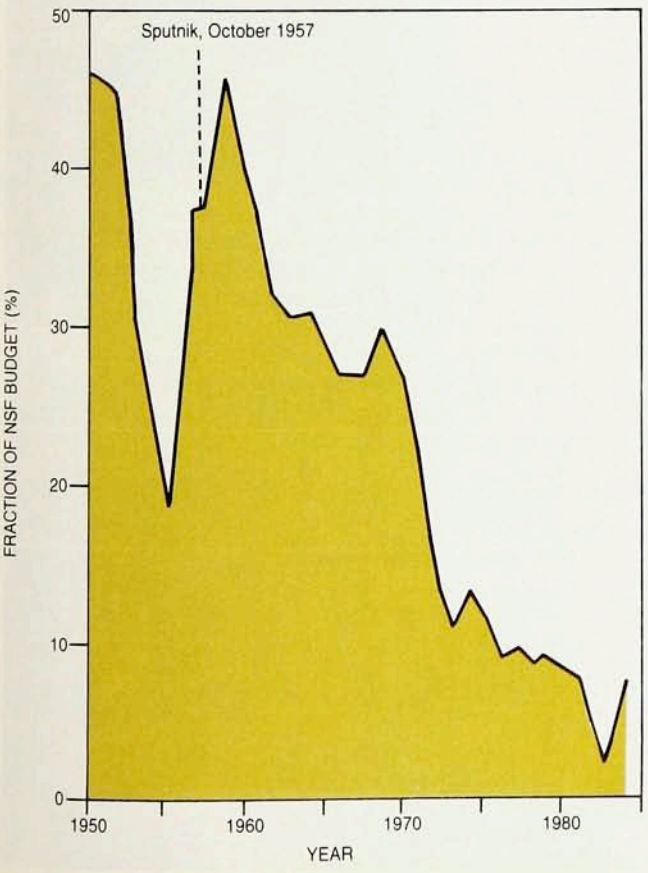
One way physicists can focus national attention on science education is to work through scientific professional societies. This past year, scientific and engineering professional societies have made major attempts to work together to develop solutions to some of the problems in science education. The Council of Scientific Society Presidents issued a statement urging that NSF's science education responsibilities be reaffirmed and that funds be provided to fulfill them. The American Association for the Advancement of Science formed a Coalition for Education in the Sciences with representatives from its affiliated societies.

Many physics societies have also focused increased attention on science education. The American Institute of Physics chose the "Crisis in Physics Education" as the topic for its recent annual symposium at its Assembly of Society Officers. AIP plans to help solve problems in science education by gathering statistics and enhancing the public awareness of the problems. The AAPT Crisis Committee has compiled a list of possible solutions to the problems of physics education and has begun to act on several of these. One AAPT committee is currently producing a kit of materials for teachers who have not been trained to teach in their current subject area, to sustain them until retraining is possible.

Individual physicists can also make a difference. If you work at a college or university, find out who your local liaison to the APS–AAPT College–High School Interaction Program is and volunteer to help support activities for the schools in your area. Encourage students to consider careers in high-school physics teaching by telling them about programs of forgivable loans and about special opportunities for physics teachers in your area. Lobby for higher teacher salaries.

If you work in industry or at a national laboratory, check to see if there are opportunities for summer employment for physics teachers. Are there physicists who will visit schools and present information on physics, technology or careers in science? Perhaps you can organize an exchange program between your lab and a local high school. You might also check to see if there is outdated but still useful equipment that could be donated to a school.

Now is the time for physicists and all scientists to become involved in science education in our schools. Each of us can have an impact.



Science education funding. Plot shows the fraction of the NSF budget that has been devoted to science education, as a function of year.

References

1. More detailed information on any of the individual projects mentioned in this article may be obtained from the authors.
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4. Edith Ruina, *Wanted: More Women in Science and Technology*, available from Committee on the Status of Women in Physics (see reference 3).
5. Regular reports on the status of science education bills in the US Senate and House of Representatives appear in *The Chronicle of Higher Education*. □