Science Shy, Science Savvy, Science Smart

By Deborah C. Fort

If the large majority of tomorrow's citizens don't achieve scientific literacy, society may be in peril, Ms. Fort warns, for ignorance in the postindustrial era can devastate the planet.
AMERICANS OF all ages and in all walks of life tend to be scientifically and technologically illiterate. And what we do not know, we fear — and approach with anxiety, if we approach it at all. Many readers of the Kappan march with this huge science-shy majority. In 1988 Jon Miller, in an editorial in the American Scientist, estimated that this nation's population is only 5% "scientifically literate." For the U.S. to remain strong and free, this percentage needs to change drastically. To borrow Kenneth Prewitt's phrase, the majority must become "science savvy." A small minority, perhaps, will remain science shy in spite of educators' best efforts, while another minority, those gifted in science, will find opportunities to become "science smart."

It is obvious that no one can become either smart or savvy about science and technology without exposure to them. Yet, with rare exceptions, Americans are born into science-shy homes in science-shy communities and attend science-shy schools, where they study science-shy curricula, taught by science-shy teachers, who use science-shy approaches (lectures and textbooks) and are governed by science-shy administrators.

In science, even the experts are in some ways shy. One practicing biologist, who in his boyhood read Scientific American from cover to cover, laments that now he...
can’t even understand all the articles in his own field. Why? Because, as Paul DeHart Hurd writes, “Biology, chemistry, physics, geology have been fractioned into 40,000 research fields represented by more than 70,000 journals, 29,000 of which are new since 1978. No scientist today would claim to know the whole of a discipline.” If this specialization poses a problem for scientists, what must that mean for students and teachers? Hurd estimates that “high school chemistry teachers who do not do their homework this weekend will be 3,000 discoveries behind on Monday morning.”

But the complexity of exploding scientific fields, which means that no one can understand everything, does not mean that no one can understand anything. The latter, however, is a widespread assumption whose pervasiveness and gravity must be acknowledged before citizens and educators can fight it effectively.

The power of astrology and creationism are merely obvious landmarks on the science-shy landscape. Though the figures are hard to pin down, more people seem to make their living in America by astrology than by astronomy. Of the 108 seventh- and eighth-graders and 11 faculty members that my science-savvy daughter surveyed in a District of Columbia public middle school in the spring of 1990, 61% believed the creation story “as told in the Bible.” In comparison, nearly half of Americans surveyed in 1988 by the Public Opinion Laboratory at Northern Illinois University “believed that the human species is descended from earlier animals.”

The power of creationism to invade biology classrooms and of astrology to act on national policy are but two specific symptoms of a larger disease. An even greater danger of scientific illiteracy lies in the ignorance many share of the fundamental scientific and technological principles that underlie “postindustrial” reality, coupled with the widely shared conviction that this failure of understanding is inevitable and inescapable. Admitting ignorance may be a virtue, but accepting it in inapproposely absolute people of their responsibility to make intelligent decisions.

The destructive potential of the products of scientific investigation and technological development makes peace on earth (and environmental peace with the Earth) not merely desirable but essential. Positive technological advance offers the only chance for the planet’s survival. The world has indeed become a “global village,” where:

- a thug in the Persian Gulf can bring a quarter of a million Americans to Saudi Arabia, ruin the area’s ecology, provoke the use of billions of dollars of weapons to take thousands of lives, and remain in power;
- democracy on one continent can fuel a successful social revolution a world away;
- a memo penned in Iowa City can be read in Moscow just minutes later; and
- a nuclear accident in Chernobyl can affect 400 million people, causing “31 directly attributable deaths, as many as 28,000 delayed cancer fatalities, evacuation of 116,000 people, and [dangerous] ground deposits . . . in communities as far away as 2,000 kilometers.”

“Cultural evolution should not be understood, any more than biological evolution, in terms of movement from bad to good or good to better,” writes O. B. Hardison. “Its absolute direction is best symbolized by an arrow pointing down a dark corridor. There is, however, a unifying theme. Every advance in culture has been an advance in communications and has encouraged ever-larger organizations of the human beings who produced it. . . . With every day that passes, it becomes a little more impossible for us to act or think otherwise than collectively.”

Both the world and the village depend on increasingly complex technologies. Over half of the laws the Congress passes involve some aspect of science or technology, and that number continues to increase. For participatory democracy to succeed, for voters to make informed decisions about their lives and their environments, for choices to be logical, citizens — including students, teachers, and administrators — must become familiar both with fundamental scientific principles and with their impact on society through technology. As Robert Hazen and James Treffil point out:

It’s obvious that if we want people to be able to understand issues involving genetic engineering, then we have to tell them what genetic engineering is. . . . If we expect people to come to an intelligent decision on whether billions of dollars should be spent on a superconducting supercollider, we have to tell them what an accelerator is, what elementary particles are, and why scientists want to probe the basic structure of matter.”

Defeating scientific innocence is a twofold process that involves method and attitude as well as content. The goal is achieving literacy in science, which can be defined as “an understanding of the norms of science and [a] knowledge of major scientific constructs,” as well as an “awareness of the impact of science and technology on society and the policy choices that must inevitably emerge.”

Prewitt focuses on the necessity of building a science-savvy population that “understands how science and technology impinge upon public life. Although this understanding would be enriched by substantive knowledge, it is not coterminous with it.”

Changing the attitude of the public toward science is essential. So, I would argue, is improving the substance of the public’s knowledge. But what is needed in this instance is general rather than specialized information. Once we have decided as a society that science must be part of our working knowledge, help can be found. Many scientists, teachers, parents, administrators, and organizations are eager to improve science education.

CHANGING THE ATTITUDE

People in general and students and teachers in particular will come to understand and have confidence in their knowledge of science and technology only when they actively experience these disciplines as they exist in reality (where they have power and beauty) rather than as they exist in educational frameworks (where they are often neutered). Fortunately, “the real stuff of science and technology is everywhere. Neither science nor technology will go away, and on some level each is comprehensible to anyone who will work to understand it.”

The physicist and Nobel laureate Erwin Schrödinger wrote of work in his field: “If you cannot — in the long run — tell everyone what you have been doing, your doing has been worthless.” His matter-of-fact insistence on the accessibility of quantum physics offers a
model for teachers. Teachers and students approaching any field of knowledge or investigation — including but not restricted to science — would do well to begin with the attitude that they can understand. To acquire that understanding, they might begin by asking themselves the following questions: What do I know? How do I know it? How well do I know it? Is it true? A wise teacher would also ask, Is it kind?

Such a positive attitude is by no means shared by most Americans — students, parents, teachers, or other educators. They haven't heard Schrödinger, or they don't believe him. They are the science shy. The science savvy make up most of Miller's 5%. The science smart — practicing, teaching, and aspiring scientists and technologists — are an even tinier group.

The job of educators, then, is to open the world of science first to themselves and their colleagues and then to their students — shy or savvy or smart. They can do this in part by actually learning more and in part by admitting to their students and themselves that what they don't know about at the moment can be explored. As Saul Brandwein wrote almost 30 years ago, "The only certainty is uncertainty. The way of the scientist... is not a calculus of discovery but... an art of investigation. In the long run the scientist knows a kind of success, but daily it comes from intelligent failure." More recently, addressing himself both to discipline-bound humanities types and to equally straitjacketed technical careerists, Arnold Arons asked, "How can we expect the students to cease running from anything that makes them feel intellectually insecure if we persist in running ourselves?" 14

Many Kappan readers are in a position to change children's schooling — and their wider environments, what Brandwein calls their "ecologies of achievement" — so that education stops coming between students and science. In my case and that of my older daughter, science-shy schooling combined with a wider science-shy environment to produce, not surprisingly, science-shy adults. Not until I began to edit papers in science and science education did I begin to overcome my background. This change in my attitude has meant that my younger daughter has always been science savvy and has a chance, given her determination, to become science smart. Learning to assume that, if an individual cannot understand something, there may be something wrong with the process or the explanation is an essential first step in developing a science-savvy population.

IMPEDEMENTS

If America's efforts to broaden exposure to and improve education about science are confined to work in the schools alone, our failure is inevitable. Not only are the schools inequitably equipped to teach all children, but the social conditions that prevent much academic achievement also impede improvement in learning science. Reform must target social conditions as well as curriculum and instruction.

Years ago, Lawrence Cremin pointed out what is too often forgotten: asking schools and teachers to do what only the community and home can do is unfair and counterproductive. 15 Cremin's wisdom, often overlooked during waves of "school reform," has been recently and powerfully restated, with statistical support, by Harold Hodgkinson in the pages of the Kappan. He writes that educators alone cannot "fix" the problems of the community and home can do is unfair and counterproductive. 15 Cremin's wisdom, often overlooked during waves of "school reform," has been recently and powerfully restated, with statistical support, by Harold Hodgkinson in the pages of the Kappan. He writes that educators alone cannot "fix" the problems of the community and home can do is unfair and counterproductive. 15 Cremin's wisdom, often overlooked during waves of "school reform," has been recently and powerfully restated, with statistical support, by Harold Hodgkinson in the pages of the Kappan. He writes that educators alone cannot "fix" the problems of the community and home can do is unfair and counterproductive. 15

The forces supporting science shyness are neither negligible nor new. Like my science-shy daughter, I loathed my college science classes, worked very hard in them, and was rewarded with barely average grades. Her experience and mine are far from unusual. Sheila Tobias re-
ently cast light on the reasons so many students leave science forever in their undergraduate years. She notes that the expectation of many university-based teaching scientists is that "the next generation of science workers [will] rise, as they did, like cream to the top." For this reason, "introductory college science courses remain unapologetically competitive, selective, and intimidating, designed to winnow out all but the 'top tier.'" In her discussion of a typical two-semester introductory physics course, which is designed to weed out those unworthy of further study of chemistry, physics, engineering, premedicine, and biology, Tobias cites the following figures:

Because it "serves" so many other fields, [such a course... will be taken by upwards of 100,000 American college and university students each year.] of whom about 1,000 will go on to get the Ph.D. degree in physics. (Another 150,000 study the less rigorous, noncalculus-based introductory physics course.) One structural problem exists at the outset: the professor is training physicists; the students, for a variety of reasons, are taking physics.\[1\]

Werner Heisenberg's belief, expressed in 1958, that "even for the physicist the description in plain language will be a criterion of the degree of understanding that has been reached"\[2\] escapes many typical teachers of introductory college physics. It also eluded both my own and my daughter's high school physics teachers.\[3\]

Bad as our secondary science education was, though, it was much more extensive than that of most Americans. However, our exposure to science in elementary school was typical: like most pupils, we studied science by reading a textbook for roughly 25 minutes a week. While most high school students breathe a sigh of relief and quit science forever after ninth-grade biology, my daughter and I stuck it out grimly through high school. I hung in until I met my Waterloo in physics class; my daughter made it through that course as well. By the end of high school, we, like about 85% of our peers, had joined the science-shy population — those who are willing to use technology's products but who say, sometimes with pride, sometimes with a certain shame, that they "can't understand science." Most remain shy for the rest of their lives.

Other thinkers have discussed the split between science shy and science savvy — so real, so unnecessary, and so very dangerous — in other terms: the two cultures, the romantic versus the classic, the artist versus the scientist, the humanities versus technology, and so on. In terms of schooling, the achievers split into the science or math/science group — the "geeks" or "natskys," as this small group of mostly boys is called at Cambridge University — and the "English" or "humanities" branch, including many girls, who are readers and writers of fiction, poetry, and other nontechnical words.

My science-shy daughter believes firmly that there are two ways of thinking — scientific and other. Tobias summarizes a report by Abigail Lipson. The Concentration Choice Study, 1978-1983, which is based on a data set of students at Harvard and Radcliffe. Focusing on students who came to college expecting to major in science and then changed their minds, Lipson found, among other things, that, like my daughter:

Most students feel there are "inherent differences" between the sciences and the nonsciences. The sciences are more certain, less abstract, more fact-oriented, more memorization-oriented, more focused, more neat and orderly, more predictable, and more analytic than the nonsciences. In contrast, the nonsciences are perceived by students, particularly those who switched out, to be more self-expressive, more personal and personally relevant, more creative, more understanding-oriented, more expansive, and more "synthetic" than the sciences.\[4\]

**TOWARD SCIENCE SAVVY**

Many scientists communicate beautifully and clearly about what they do in ways that both students and their teachers can understand. To use Robert Pirsig's metaphor from Zen and the Art of Motorcycle Maintenance, the motorcycle and its workings are as meaningful as the countryside through which its riders pass. Pirsig says that "flight from and hatred of technology is self-defeating." He continues, "The Buddha, the Godhead, resides quite as comfortably in the circuits of a digital computer or the gears of a cycle transmission as he does at the top of a mountain or in the petals of a flower." Some understanding of what science is can help students overcome their fear. But first, a few things that science is not:

- Science is not the "scientific method," tediously memorized by countless children from before my school days to beyond those of my daughters.
- Science is not simply the "hands-on" experiences that are today's glowing buzz words in many science education circles. Lorraine Dayson may be right that "world views begin with in-the-fingers knowledge," but she would be the first to admit that they don't end there.\[5\]
- Science is not the watered-down, but nonetheless incomprehensible, compendiums that serve as textbooks for many introductory precollege science courses. Hurd calls these books "beautifully illustrated dictionaries." He has also pointed out that students learn more new words in many science classes than they do in introductory language courses.
- Science is not the "weed-them-out" introductory science courses that Tobias describes and analyzes.

In short, science is being severely misrepresented throughout our education system. There are no panaceas at any educational level, though many are offered — often by decent, committed people who genuinely believe that they have the cure for "what's wrong with science education" in America. Some general directions, however, are suggestive.

The science to which all should be exposed in all environments is uncompartmentalized; it is everywhere. One way to approach it is through the broadest possible curriculum in the elementary and early high school years. Science includes the humanities, and the humanities include science. The American Association for the Advancement of Science's Project 2061 emphasizes this interdisciplinary approach (see "A Few Resources"). The way of the scientist deepens beauty by increasing understanding.

**EMBRACING TECHNOLOGY**

What about technology? While some fear both the power of technology that is out of control and the idea of being dependent on badly understood forces, the
American public "overwhelmingly" (88%) believes that "the world is better off because of science" (here not considered separate from technology). But among these enthusiasts, 38% in 1988 and 55% in 1983 also thought that, "because of their knowledge, scientific researchers have a power that makes them dangerous." 31

Technology precedes science. Technology was evident when the first "cave-person" used a slingshot to fell dinner. Hurd notes that more Nobel Prizes are awarded for technology than for science. 28 In fact, James Rutherford, head of Project 2061, has said that "technology is coterminous with humanity; math is later; what we call science today is the newcomer — about 300 years old. The power of the three is not that they're the same but that they're inextricably inter-related." 30

Lewis Mumford's definition of "technics" is still relevant. Technics is "a translation into appropriate, practical forms of the theoretic truths, implicit or formulated, anticipated or discovered, of science. Science and technics form two independent yet related worlds: sometimes converging and sometimes drawing apart." Mumford goes on to quote Leonardo: "Science is the captain and practice [technolgy] the soldiers." But, Mumford adds, "sometimes the soldiers win the battle without leadership, and sometimes the captain, by intelligent strategy, obtains victory without actually engaging in battle." 31 Brandwein blurs the distinction in this way: "America was discovered, the United States was invented, [but] in our time science and technics are the two arms of the same organism, society." 32

Many children are instinctive masters of some of the newest technologies. While the middle-aged often shrink from computers, 8-year-olds are frequently their rulers. Many children don't want to simply use a watch, a computer, or a car; they want to know how it works and are willing to explore on their own to try to find out. As they do, they begin to move from the technology that "hooked" their interest into the science that produced it. Almost all American youths live in technologically advanced environments. (Even those in low socioeconomic groups are exposed outside their homes.) Once the pupils become interested, schools can work to create places and ways to encourage that interest to grow.

It is not too late for any of the children in our schools today. "Gifted" students do well in school by dint of their environment — which includes both their genetic endowment and, probably even more important, their social surroundings at home, in the community, and sometimes at school. These "gifted" students (boys and girls alike) should have a chance to discover an interest in science, in English, in math, and in many other fields — often simultaneously. So should all students. But the gifted make up only a small percentage of the school population — probably no more than 20%. The science smart, a tiny group even among these students, are now usually males.

Both the gender imbalance and the percentages need to change radically. The science savvy should be the large majority; the science shy, whose disappearance should be a goal for American educators, should at the very least become the small minority. And if most students emerge savvy, more of both genders will have a chance to uncover their "smarts."

IMPROVING CONTENT

To improve their own science backgrounds and to widen their knowledge of techniques, teachers can take advantage of various resources at the school, local, and national levels, as well as numerous inservice training programs. The latter are run not only by colleges and universities but also by business and industry, by professional associations, and by other groups (see "A Few Resources"). But, fundamentally, educators and their students must investigate independently to become science savvy, to acquire street sense in science and technology. 33 The best teachers for teachers are other teachers.

In 1960 Jerome Bruner offered a useful model for helping teachers approach what looks overwhelmingly complex. His advice was, in brief: "The basic ideas that lie at the heart of all science and mathematics and the basic themes that give form to life and literature are as simple as they are powerful. To be in command of these basic ideas, to use them effectively, requires a continual deepening of one's understanding of them in progressively more complex forms." 34 Virtually no one believes that complexities can or should be altogether eliminated, but they should not be presented until a solid groundwork of understanding has been laid. To begin with complexity is to try to run before learning to walk, and often
neither students nor teachers know how to walk. Walking is essential for science savvy.

The implications of Bruner's statement for the teaching and learning of science are clear. An approach could be usefully organized around the five questions I proposed earlier as the first step toward learning any subject. Overarching concepts, such as those Bruner mentions and Brandwein defines, could offer useful bases for inservice training courses to help teachers who have become out of touch with scientific and technological advances. Like the National Science Teachers Association proposal for secondary school science curricula (see "A Few Resources"), Brandwein's approach for elementary school dispenses with the artificial division of science into disparate fields.

Courses in science and technology and useful approaches to them can probably best be offered by other teachers who have field-tested their ideas and are thus sharing known commodities. On the model of the National Writing Project, the teachers who signed up as students could then "give back" their knowledge to their colleagues in the schools where they work. This method underlies many "teacher enhancement" projects now under way, including the Department of Education's Eisenhower Program for Mathematics and Science Education and some of the efforts funded by the National Science Foundation (NSF).

Teachers might also enlist the aid of local figures outside the school system — scientists, parents, businesspeople, and engineers. Such individuals care about and have more to offer the young than many educators guess.

In addition, teachers and students should be encouraged to read the "science sections" of their local and national newspapers, as well as such magazines as Science News, National Geographic, Natural History, Discover, and Smithsonian. Science writers, scientists who write, and historians of science — whose business it is to make science accessible to nonspecialists — could play an essential role in increasing science literacy.

Books that approach science and technology in their larger contexts encourage cross-disciplinary literacy. Hardison's ambitious attempt in Disappearing Through the Skylight to meld literature, art, and architecture with science and technology and to place them within the context of social and cultural history both assumes and leads to science savvy among nonspecialists. Good science texts offer clear explanations, and, in the current tilt away from textbooks, it is important to remember that not all textbooks should be rejected. There are also wonderful trade books on science for children — books that smart librarians slip into the adult sections to entice science-shy readers older than 10 into learning about science. Everyone old enough (and that's not very old) should be introduced to the joy of reading the prose of scientists such as Lewis Thomas, Loren Eiseley, Isaac Asimov, and Stephen Jay Gould, to mention only a few.

In the preface to his book Wonderful Life (named for the Frank Capra film), Gould defines his audience:

The concepts of science can be presented without any compromise, without any simplification counting as distortion, in language accessible to all intelligent people. Words, of course, must be varied, if only to eliminate a jargon and phraseology that would mystify anyone outside the priesthood, but conceptual depth should not vary at all between professional publication and general exposition. I hope that this book can be read with profit in seminars for graduate students and — if the movie stinks and you forgot your sleeping pills — on the businessman's special to Tokyo.

Gould's book can also be read in high school and college science classes for the science savvy, as well as in classes for the science smart.

Science-shy teachers in the schools will find concrete suggestions — from other teachers — in a number of magazines and journals (see "A Few Resources"). High school teachers should also be aware of several ambitious, serious, and potentially helpful programs (some of which are mentioned in "A Few Resources") that are being developed to improve the teaching of science in high schools. Many of these recommendations — like the still-valid curricula developed under NSF auspices in the 1950s and 1960s for students at all levels and now being collected by the Department of Education's Eisenhower Clearinghouse (see "A Few Resources") — aim primarily at turning the science shy into the science savvy. At the same time, however, they offer rich environments that can also help students uncover their gifts and become science smart.

One of the major jobs facing educators is to create or uncover environments in which the science shy can first discover and then "follow their bliss," as Joseph Campbell put it. The doors must swing open both for teachers and for the roughly 80% of students in our schools who have not been lucky enough to find themselves in home and community environments that encourage the exploration of science and technology. Overcoming the majority of their fear and loathing of science and technology can be achieved by the same means that the science smart uncover their aptitudes: exposure. Exposure to science and technology should be as exciting in school as it is in the community as a whole — and perhaps deeper.

The science smart — those who select themselves into the scientific fast lane — can be well served by the same approach as the science shy. Schooling and education need to foster opportunities for them to try their hands in real scientific work. Just as the talented writer needs an opportunity to publish, the student interested in biology needs the chance to complete a work of science, an experiment.

Not everyone needs to understand science as a scientist does — indeed, not everyone can — but the large majority must understand as citizens who have enough science savvy to make intelligent decisions. Among the fundamental questions Americans must resolve are, as Edith Brown Weiss puts it, whether and how to exercise "the power to alter planet Earth irreversibly, on a global scale, and in many different ways. The depletion of the ozone layer, the increasing rate of species extinction, the disposal of hazardous wastes in vulnerable areas, and the loss of arable soils are just a few of the many global environmental changes that will affect the well-being of future generations."

The change of approach that Tobias proposes for introductory college science classes is similar to that which Hurd proposes for high school classes. At all levels, beginning science classes designed to prepare students for scientific careers should be replaced with experimentally
based courses. Prewitt puts it clearly:

"Schools should teach science in a man-
ner that opens up personal opportunities
for all their graduates, not just for those
whose career choice is science or en-
gineering."

One way to approach the worlds of
science and technology is through themes
with clear social relevance. One such
avenue is ekistics, which Brandwein
defines as "that [interdisciplinary] field
of study, that area of knowledge, and the
concepts and values through which
hummankind recognizes interdependence
with the environment as well as respon-
sibility for maintaining a culture that . . .
sustain[s] a healthy . . . environment." Other
specific issues whose scientific and
 technological components might be ex-
plored include AIDS, drug addiction, and
pollution. All of these problems require
real solutions but may not have them.
Hurd suggests:

There are also problems that require
an understanding of risk, probability,
uncertainty; they are problems likely
to have multiple solutions and involve
a combination of short- and long-term
decisions. As with most problems we
face in life, they have a cross-disci-
plinary perspective. Human affairs in-
volving science and technology tend
to have social, political, and economic
implications. That is why science is
best taught across subject fields in-
cluding the arts and humanities."

THE STAKES

The stakes for making the science sav-
vvy rather than the science shy the majori-
ty in our nation are very high. In an en-
riched environment, some students who
would otherwise not know of their talent
for and interest in science will "take off"
— choosing to do work beyond what is
required. Without an improvement in our
current system of science education, not
only will these students suffer, but also
the society that counts on their contribu-
tions will be the poorer. And if the large
majority of tomorrow's citizens don't
achieve scientific literacy, society may
not merely be at a scientific and tech-
nological standstill; it will be in imminent
peril, for ignorance in the postindustrial
era can devastate the planet.

Without the opportunity to learn and
understand science and its contributions
to society, an opportunity most of us did
not have and most of our children and
students still do not have, we are all in
trouble. This is why science must both
grow from and equip us for real-world
experiences, for approaching and cop-
ing with realities and problems that may
not have solutions. Our students, how-
ever, won't grow up in the same world
we grew up in, and their world will have
changed largely through technological
advances. They must be prepared for
their new world — not one we define but
one they must cope with. On their own
the schools cannot create informed and
competent citizens, but they can help.
The alternative is not reassuring. A
science-shy public supported by a science-
shy Congress could threaten the sur-
ival of the nation and the world. In 1989
Walter Massey, then director of the NSF,
went to President Bush: "I would sug-
gest that you appoint no one as your sci-
ence adviser who cannot explain to you
in a language you can understand the im-
portant scientific and technological issues
that will confront you. Anyone who says
'It is too technical for me to explain to
you' should be replaced immediately." As
citizens of a democratic society, we all
share this responsibility to make un-
derstanding inform our actions and
decisions.

2. Kenneth Prewitt, "Scientific Literacy and Dem-
3. Paul DeHart Hurd, "Science Teaching in a New
   Key for the 21st Century," paper presented at the
   Sacramento Area Science Framework Conference,
   22 October 1990.
4. Ibid.
5. Quoted in National Science Board, Science and
   Engineering Indicators — 1989 (Washington, D.C.:
   p. 168.
6. Ragnar E. Lofstedt and Allen L. White, "Overview:
   International: Chernobyl: Four Years Later, the
   Repercussions Continue," Environment, April
   1990, p. 4.
7. O. B. Hardison, Jr., Disappearing Through the
   Skylight: Culture and Technology in the Twentieth
8. Benjamin Shen, "Scientific Literacy and the Pub-
   lic Understanding of Science," in Stacey Day, ed.,
   Communication of Scientific Information (Basil:
   Karger, 1975).
9. Robert M. Hazen and James Trefil, Science
   Matters: achieving Scientific Literacy (New York:
    and Empirical Review," Daedalus, Spring 1983,
    p. 30.
11. Prewitt, p. 56.
12. Erwin Schrödinger, Science and Humanism:
    Physics in Our Time (Cambridge: Cambridge
13. Paul F. Brandwein, Elements in a Strategy for
    Teaching Science in the Elementary School (New
15. Paul F. Brandwein, Memorandum: On Renewing
    Schooling and Education (New York: Hackett
16. Lawrence A. Cremin, The Genius of American
    Education (New York: Random House, 1966), pass-
    im.
17. Harold Hodgkinson, "Reform Versus Reality,"
    Phi Delta Kappan, September 1991, p. 16.
18. Committee on Education and Human Re-
    sources, By the Year 2000: First in the World
    (Washington, D.C.: Office of Science and Tech-
    nology Policy, Federal Coordinating Council for
    26.
19. In the Public Interest: The Federal Government in
    the Reform of K-12 Math and Science Education
    (New York: Carnegie Commission on Science,
20. Sheila Tobias, They're Not Dumb. They're Dif-
    ferent: Stalking the Second Tier (Tucson: Research
    Corporation, 1990), p. 9. Single copies are avail-
    able for $2; additional copies are $.50 each from
    Science Service, 1719 N St. N.W., Washington,
    DC 20036. Ph. 202/785-2255.
22. Werner Heisenberg, Physics and Philosophy:
    The Revolution in Modern Science (New York:
23. At both the secondary and university levels, our
    teachers seem to embrace, instead, Heisenberg's
    earlier (1925-26) perplexity. Defending the "new
    quantum mechanics" to Einstein, Heisenberg mused,
    "For the time being, we have no idea in what lan-
    guage we must speak about processes inside the
    atom... I assume that the mathematical scheme
    works, but no link with the traditional language has
    been established so far." See Werner Heisenberg,
    Physics and Beyond: Encounters and Conversations,

A Few Resources

LOCAL SOURCES

Many kinds of help are available to move from shyness to savviness where science is concerned. People in local communities are often able and willing to talk to teachers and students. Try scientists, engineers, technologists, industrialists, workers in specialized fields, museum staff members — anyone who cares about education in science. Parents, politicians, and businesspeople may have a variety of slightly different reasons for wanting science-savvy and science-smart students. Some may be thinking in terms of international priorities. Others may want a competent workforce in their industries. Still others may remember their own mentors and want to begin to give back what a generous teacher (not necessarily one working in a classroom) offered them. Many organizations — museums, businesses, laboratories, others — might also be willing to make contributions.

NATIONAL GROUPS

In addition to local sources, national associations in science, education, and science education have been working to improve the teaching of science at all levels and in many environments. Brief descriptions of some of their approaches follow.

For years the American Association for the Advancement of Science (AAAS) has been working on Project 2061, a long-term series of publications designed to help reform the nation’s science, mathematics, and technology education at all precollege levels. The AAAS published *Science for All Americans* and five panel reports (biological and health sciences, mathematics, physical and information sciences and engineering, social and behavioral sciences, and technology). Among other suggestions, these reports call for softening the boundaries between traditional subject-matter categories and reducing the detail that students must try to remember. For further information, contact the American Association for the Advancement of Science, Project 2061, 1333 H St. N.W., Washington, DC 20005. Ph. 202/326-6666.

The Washington-based National Science Resources Center is building a nationwide network of teachers and scientists interested in improving primary school science. The center is also compiling a collection and computer database of science teaching materials for the elementary grades. Co-sponsored by the National Academy of Sciences and the Smithsonian Institution, the center prepares and periodically updates a comprehensive inventory of elementary school science teaching resources. Its *Science for Children: Resources for Teachers* (1988; update expected 1994) includes sources of information and listings of periodicals, museums, and professional organizations. The center is expanding its collection to include resources for teaching science in middle schools and junior high schools. For further information, contact the National Science Resources Center, Smithsonian Institution, Arts and Industries Bldg., Rm. 1201, Washington, DC 20560. Ph. 202/357-2555.

The National Science Teachers Association set forth specific K-12 science education recommendations in its 1982 (revised 1985) position statement, *Science-Technology-Society*. The ongoing Scope, Sequence, and Coordination Project will continue to issue curricular suggestions. In 1992 the project, with generous funding from the Department of Education and the National Science Foundation, produced two books: *The Content Core: A Guide for Curriculum Designers and Relevant Research: A Collection*. The group is developing and implementing at six centers nationwide an instructional sequence that not only increases but also integrates the study of biology, chemistry, physics, and earth and space science across the secondary years. As students mature from sixth to 12th grade, the emphasis of science study gradually shifts from descriptive and phenomenological to empirical and quantitative to theoretical and abstract. For further information, contact Scope, Sequence, and Coordination, National Science Teachers Association, 1742 Connecticut Ave. N.W., Washington, DC 20009. Ph. 202/328-5800.

All the major associations for science teachers publish journals that offer concrete suggestions for ways to improve the teaching of science. For example, *The Biology Teacher* and *The Physics Teacher* provide field-specific approaches primarily for secondary teachers. The National Science Teachers Association publishes *Science and Children* (for teachers of pre-K-8), *Science Scope* (for middle school and junior high teachers), and *The Science Teacher* (for high school teachers).

FEDERAL PROGRAMS

The fourth of the six national goals for education states that U.S. students are to be "first in the world in mathematics and science achievement" by the year 2000. A good deal of federal help is available to educators who wish to move toward meeting this goal. Four federal initiatives aiding science education, all stressing learning as a continuum from prekindergarten through higher education, however, merit special mention.
Nearly a third of the nation's math and science teachers have benefited in some way from Eisenhower grants.