EDUCATION REFORM

U.S. Tries Variations on High School Curriculum

The traditional sequence of biology, chemistry, and physics in U.S. high schools, say reformers, may be at the root of poor student performance

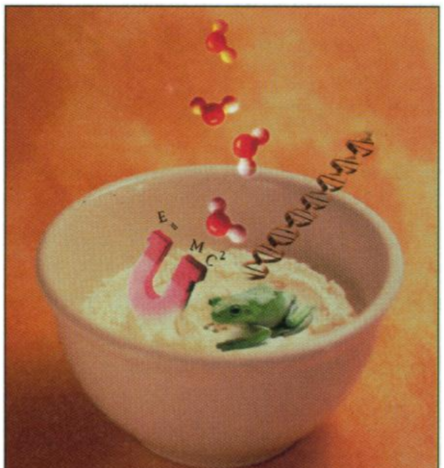
Gary Freebury has participated in an alphabet soup's worth of federally funded attempts to reform the U.S. high school science curriculum in the past decade. The Kalispell, Montana, high school chemistry teacher wrote a preliminary version of what later became Scope, Sequence, and Coordination (SS&C), a national effort to "teach every student, every subject, every year," and later crisscrossed the country helping teachers work with the new course material. He also helped add a science component to the state's $10 million Systemic Initiative for Montana Mathematics and Science.

Last month, the 62-year-old Freebury retired after 35 years at Flathead High School—and took on yet another project to improve U.S. science education. He's hoping to convince state officials to adopt a reform called American Renaissance in Science Education (ARISE), which would reverse the traditional order of teaching the four core disciplines, starting high school students out with physics rather than biology (see Policy Forum, p. 178). "I think it's the right way to go because it's so logical," says Freebury, who believes that a national effort will help him in Montana.

Teachers like Freebury are in the vanguard of efforts by governments, organizations, and even individual schools to change a century-old system of teaching high school science. The United States stands alone among industrialized countries in offering its high school students a series of yearlong courses each consisting of a single science subject. As a rule, the sequence begins with biology and proceeds through earth sciences, chemistry, and physics, with enrollment dropping off at each step until fewer than 20% of U.S. students ever take physics. That approach may work fine for producing Nobel laureates, say educators, but it's not effective for the average student. Bill Schmidt, a science educator at Michigan State University in East Lansing, calls it "the plop-fizz approach: We drop students into a class and expect them to learn everything there is to know about a subject in 1 year." The result, he says, is a mile-wide, inch-deep curriculum that frustrates students. A dismal performance by U.S. seniors on the recent Third International Mathematics and Science Study (TIMSS), for which Schmidt was the U.S. coordinator, is seen as the latest evidence of the flaws in such an approach (*Science*, 27 February, p. 1297).

Reformers say that by teaching biology first, the present curriculum also fails to do justice to the increasingly quantitative science it has become. "Science has a hierarchical nature and right now, although I hate to admit it, molecular biology is at the top of the heap," says Leon Lederman, the Nobel Prize–winning physicist and education activist who put together ARISE. Concepts

ANN ELLIOTT CUTTING



MIXING UP THE DISCIPLINES

from physics and chemistry are crucial in biology, he says. "Unfortunately, our curriculum doesn't reflect those connections."

Attempts to reorder science teaching come in a variety of flavors: Integrated, inverted, and coordinated science are the most common labels. But regardless of their differences, all try to entice more students into science by offering a different sequence of subjects and emphasizing labs, group projects, and other hands-on activities instead of lectures. They also try to encourage teachers to erase the boundaries between disciplines. The idea behind many of these efforts is to emulate Europe and Asia, where middle school students begin a cyclical curriculum that covers all the sciences each year in progressively greater detail and depth. "The top-achieving countries [on TIMSS], like the Scandinavian countries, are teaching physics every year since the sixth grade," says Schmidt.

But such changes are tough to implement, especially given the pluralistic nature of U.S. education across some 16,000 school districts. Ask Thomas Palma, head of the science department at North Hunterdon High School in New Jersey and a 34-year classroom veteran. Palma anticipated ARISE by nearly a decade when he lobbied the powers that be to invert the science curriculum and make ninth-grade physics mandatory. "People ask me why more schools haven't done this," says Palma. "Well, you have to be a lunatic. I took a well-established program at a relatively affluent school district where most kids go to college and turned it upside down, with no guarantee that it would work. I had two school board members, Ph.D. physicists, who told me it wouldn't work. And 3 years ago we got a new school superintendent who said he planned to get rid of the program."

Palma and others emphasize that teaching physics earlier requires more than simply reshuffling the order of classes. It means tailoring the course to the math that students have taken, either algebra or geometry, instead of more advanced topics like trigonometry or calculus. "It's not the same physics that was traditionally taught," adds Arthur Eisenkraft, who has promoted similar reforms as science coordinator for Bedford Public Schools in Westchester County, New York.

In spite of the obstacles, Palma won over his critics and today points proudly to data showing that many more students are taking science, at more advanced levels, and doing as well or better on college-oriented national achievement tests. Moreover, last year the district's second high school, which had initially balked at the change, began to implement a similar reform.

Advocates say that such changes also can open physics to a wider audience. "Before, the only kids that took physics were our top-notch seniors," says Maureen Daschel of St. Mary's Academy, a college-prep, Catholic girls school in Portland, Oregon, which inverted its curriculum 6 years ago. "Now a lot more take a second year of physics, and the kids say they feel better prepared to do science in college." Indeed, says Eisenkraft, a fundamental aim of such reforms is to reach students with limited math skills, who otherwise would not be exposed to rigorous science courses, and give them the tools to continue on. "Our goal is to reach all students," says Eisenkraft, who teaches physics at Fox Lane High School and has also been involved in SS&C.

Even with the best material, reformers agree, well-trained and knowledgeable teachers are essential for successful implementation. For schools adopting an inverted curriculum, the biggest problem may be finding additional physics teachers—or retraining current staff—to handle the increased student load, as well as acclimating staff to a younger batch of students. Conversely, there's also the problem of how to cope with a temporary surplus of biology teachers, including some not certified to teach other subjects, as biology becomes an upper level course. "Professional development is the key, both for current and future teachers," says Rodger Bybee, head of the Center for Science and Math Education at the National Academy of Sciences and an adviser to ARISE. "And that costs money." Then there's the issue of elitism. Lederman remembers the reaction of 60 physics teachers during a workshop in which he outlined his proposal. "They gave me an ice-cold stare, as if to say, 'We don't do freshmen.'"

Instead of simply restacking the layers in the science cake, the SS&C project—spearheaded by former National Science Teachers Association (NSTA) executive director Bill Aldridge and separated into middle school and high school projects—set out to teach each of the disciplines every year with materials prepared ahead of time by the teachers themselves. But its fate illustrates the difficulties such reform efforts face. In 1996, officials at the National Science Foundation (NSF) pulled the plug on the high school portion of SS&C, which operated at 13 sites, after expressing concern about the quality of the materials. The project was halfway through its expected 4-year life. (Existing units are available online at no charge from NSTA at www.gsh.org/nsta/default.htm)

"What's so good about SS&C, in theory, is that it tried to break away from labels and create a genuine, spiraled approach," says NSTA's current executive director, Gerald Wheeler. "As a teacher, it meant I don't have to wait a whole year, while I'm doing physics, to bring up a concept in chemistry. That's closer to the real world." But Wheeler admits that SS&C failed to overcome enormous "logistical hurdles," from developing the material on time to retraining the staff to preparing students for year-end achievement tests. "You needed teachers certified in all four areas, which we didn't have at Fox Lane," says Eisenkraft. Although some schools used a rotating team of teachers to compensate for that lack of individual expertise, others say this approach disrupted the usual ties between students and teachers. And several schools have avoided integrating courses because of the risk that some students may not be adequately prepared for discipline-based tests.

Regardless of the content, any reform effort also must overcome the problem of assessing its impact on a complex and dynamic environment—what some evaluators compare to "changing the tires on a car as you're driving down the road." Aldridge has complained bitterly that NSF demanded a finished product after too short a time, and NSF program manager Wayne Sukow, who was closely involved in SS&C, admits that the impact of any major reforms is hard to gauge, at least in the short term. "You really need at least a generation of students—12 to 15 years—to study the impact of curriculum reform," says Sukow. "But it's tough to sustain interest for that long." Frances Lawrenz of the University of Minnesota, Minneapolis, concluded after a $400,000 evaluation of the SS&C's first 2 years that "it is certainly no worse than traditional science teaching." But she found "little evidence" that students had learned more or changed their attitude about science.

Old hands of school reform know how hard it is to bring about change. Shirley Malcom, head of education programs at the American Association for the Advancement of Science (which publishes *Science*) and an adviser to ARISE, thinks the project is promising "not because it's the truth and the light ... but because Leon's questioning the canon, and that's always healthy. I wish him luck, because he'll surely need all the help he can get."

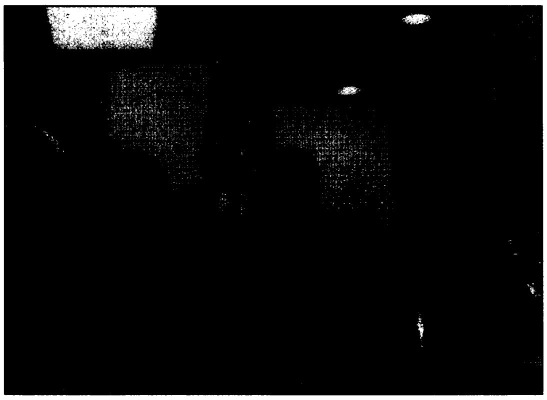
—**JEFFREY MERVIS**

KOREA

Major Reforms Proposed to Improve Science Payoffs

Korea's current economic crisis highlights the need for changes to boost the return on its large investment in research

SEOUL, SOUTH KOREA—The new government of President Kim Dae Jung has begun a comprehensive reform of science and technology (S&T) policy aimed at creating what officials call a "technology-based advanced economy." The reforms are an effort to repair a system that, both scientists and government officials agree, suffers from bureaucratic infighting, a lack of incentives for quality research, and poor links between the academic and industrial sectors. "There are serious weaknesses" in the present policy, admits Kang Chang-Hee, a legislator who was appointed this spring as minister of science and technology.



KIST

Looking ahead. President Kim Dae Jung (right foreground) visits Korea's flagship Institute for Science and Technology.

The new policies are part of a broader effort by an opposition party that has finally taken power to restructure Korea's inefficient economy. The S&T changes include a new top-level body to coordinate R&D policy, a reorganization and possible streamlining of the government's 34 research institutes, a plan to create 10 or more science and technology universities, and a decision to extend dual citizenship to scientists and engineers as an inducement to return home after studying and working abroad. Efforts are also under way to reform hiring and promotion practices within institutes and to foster innovation with large grants for high-risk, high-payoff research.

The reforms are aimed at correcting a situation in which a heavy investment in R&D—sixth largest in the world in 1995—has yielded relatively low dividends. A recent international survey combining data and the responses of global business executives, for example, places Korea 28th in terms of S&T competitiveness. The previous government aggravated the problem by a continual churning of top officials, including five science ministers in 5 years.

The new government has promised to remedy this situation, preaching efficiency. In line with that approach, planners at the Ministry of Science and Technology (MOST), which Kang oversees, want to divide South Korea's 34 publicly funded research institutes and related projects into three categories, representing basic, applied, and social science research. (MOST currently operates 20 of the institutes, which range from the Korea Institute for Science and Technology, founded in 1965, to the 2-year-old Korea Institute for Advanced Study.) A proposal to replace each institute's board of directors and president with one board for each category is under "heated discussion," says Joon Eui-Jin, director-general of the ministry's Science and Technology cooperation bureau. Some