Bottom-Up Revolution in Science Teaching

A California program relies on Soviet principles—and teachers' creativity—to put some new zip in science education

Fullerton, California—OUT IN CALIFORNIA, where it sometimes seems all revolutions begin, a new one is under way. This time the arena is science education. With minimal guidance from above, California's teachers are being encouraged to summon their ingenuity and revolutionize the way science is taught. Their equivalent of Mao's Little Red Book is a program called Scope, Sequence and Coordination, proposed less than two years ago by Bill Aldridge, executive director of the National Science Teachers Association (NSTA).

Scope, Sequence and Coordination (SSC, for short—like another big-science project) turns the traditional way of teaching science inside out. Instead of the "layer-cake" method (dating to the 1890s) in which students are taught biology in the 10th grade, chemistry in the 11th, and physics in the 12th, SSC teachers would teach each of those subjects, and earth-science as well, each year over a 5-year period. This stretched-out method is common practice in Europe, Japan, and the Soviet Union, where it's been shown to produce better retention of knowledge than the layer cake does.

As radical as Aldridge's proposal may seem, California's plan is more daring yet, due largely to the leadership of the state's science education director, Thomas Sachse. "Let the reform come from the teachers," Sachse told *Science* at a planning meeting held here last week. "Our model is to get a lot of schools [involved] and change the whole state."

And Sachse and his teachers aren't going to let their revolution get bogged down in endless planning. Beginning this fall, 10,000 students in some 100 schools around the state will be getting courses modeled on the SSC approach. But California's teacher-based—or bottom-up—plan, and the haste with which it is being implemented, has some experts, including Aldridge himself, worried. Sachse's response: given the current state of science education, there's simply no time to lose.

The SSC model that Sachse is exploiting first occurred to Aldridge two years ago when he learned how the Soviets teach science. "All of those kids are getting 5 years of physics," he told *Science*. But the physics that Soviet students learn is no more advanced than physics in U.S. schools; the difference is that the material is spread out over many years. The result? "Their retention rate is substantially higher than ours," says Aldridge.

After his Soviet epiphany, Aldridge wrote and published in the January 1989 NSTA newsletter the proposal for SSC, which he believes would bring U.S. science education into line with that of the rest of the developed world. If adopted nationwide, he says, SSC will be the first change of such magnitude in science education since 1893, when the National Education Association ruled that high school science would consist of one year each of biology, chemistry, and physics. The poor performance of U.S. students in science today is ample evidence that that system has failed, Aldridge says.

Among the other failings of the traditional method, according to Aldridge, is the fact that science has become a subject that is restricted to the top students, causing the average U.S. high school student to view science as a subject only for smart kids. "There's no excuse for making the claim that some people can't learn science," Aldridge says; "it's elitist nonsense." And he believes SSC can squelch that elitism by making science more interesting and accessible to a wider range of students.

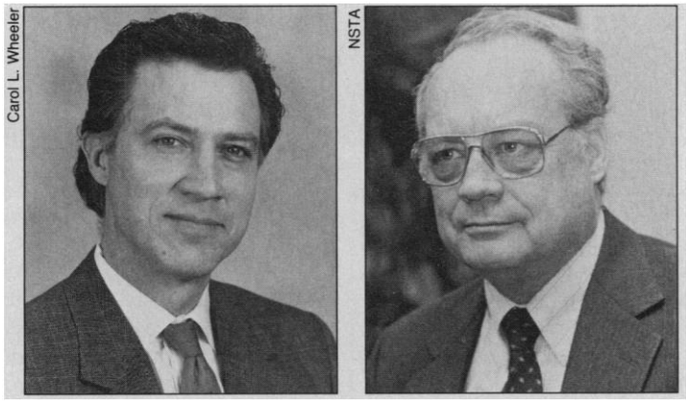
Sachse agrees with Aldridge's criticisms—and he thinks that SSC may be an important part of the answer. Soon after hearing of Aldridge's idea, he wrote a grant proposal to the U.S. Department of Education aimed at getting funds to introduce SSC in California. Last August, he received one of three $580,000 grants from the education department for developing SSC. Another went to Linda Crow, who heads a secondary education project at Baylor College of Medicine and plans to introduce SSC into three Houston schools. And the third was awarded to NSTA, which will play a coordinating role as more states and school systems adopt SSC.

Unlike the narrow-gauge Baylor project, California's plan is to introduce SSC quickly into as many schools as possible. State funds were added to the federal grant, and the state invited individual schools to apply for money to develop their own programs. Indeed, grants have been awarded to 110 high schools (and many of their associated middle schools), making a total of 214, half of which will begin teaching SSC this fall.

Dividing the relatively modest pot so many ways has meant that each school's allocation is small. But Sachse expresses faith in his bottom-up approach: "The teachers are going to make this work. We give them this nickel and dime money—8000 bucks—and they plan together; they go out and scramble for instructional materials; and they dream up this scope and sequence, with very little to work with from the national and state levels."

The few guidelines Sachse did give the teachers were not drawn only from SSC, but also from a new California framework for science education. The SSC recipe goes: Take the existing curriculum, spread it out over 5 or 6 years, and arrange it developmentally. Seventh and eighth graders should be presented with description and phenomenology; ninth and tenth graders with semi-empirical approaches; and the abstract, quantitative, theoretical concepts should be saved for those in the eleventh and twelfth grades.

As if this weren't enough, California's teachers are being challenged by Sachse to connect—and in some cases, merge—the different scientific subjects via discipline-bridging themes such as evolution, energy, patterns of change, scale and structure, stability, and systems and interactions.



Practice and theory. *Thomas Sachse (left) is using principles developed by Bill Aldridge (right) to revolutionize science education in California.*

There are as many ways of doing that as there are schools in the program. But the governing principle for all is a shift from sheer volume of facts to understanding the scientific process, says biology teacher Mike Brugh of Luther Burbank High School in Sacramento. And the trick to teaching that understanding, Brugh says, is to find subjects that will engage the students' interest and exploit them as examples of scientific reasoning.

For example, Brugh has created a unit in forensics for his ninth graders, "because kids love blood and guts." Not only does forensics use principles of physics, chemistry, and biology, but the unit will also teach students to think in the way scientists do, asking questions such as: How do you know what's true? What evidence do you have? Why do you believe it? How would you test it? "They will have to learn the skills of observation," Brugh says, "in order to tell who killed who."

Creativity like Brugh's is an asset. But with science teachers all going their own way, the result could be chaos. Yet Sachse thinks the chaos will be creative—that from it the best ideas will emerge and be widely adopted. To assist in that process, the state has set up a computer network through which teachers can share ideas.

How soon will anyone know if this revolutionary, bottom-up educational experiment is working? Evaluation of the project will begin almost immediately, with surveys to determine student interest and the effectiveness of the teaching materials. But the real test will be when the first students graduate from the 7-year program and are tested for scientific ability against their peers in traditional schools.

Meanwhile, NSTA's Aldridge is just a bit worried about the California experiment. Eager as he is to see his own idea adopted, he wonders whether California is plunging in without enough control from the top. He favors the moderate approach taken in the Baylor project, where Linda Crow will work closely with every teacher in the three Houston schools that will introduce SSC this fall. "Linda had the foresight to focus her resources," Aldridge says. "She will be meeting with her teachers each week. You can't do that when you've got 100 schools. They're going to have to rely more heavily on their own resources."

Sachse acknowledges that some of his colleagues share Aldridge's view. But he decided to put faith in his teachers and move ahead, based on the notion that science education is too desperately in need to justify waiting. "It's man the torpedoes now," he says, "if we're really serious."

■ MARCIA BARINAGA

Turning Teachers on to Science

Chicago—After a long career studying elementary particles, Leon Lederman is now making his presence felt in elementary education. The former director of the Fermi National Accelerator Laboratory has persuaded a clutch of organizations, including two federal agencies, to sponsor an ambitious effort to train 17,000 Chicago public school teachers in science and math. The goal is to expose 3000 teachers a year to the latest techniques for teaching science and math to kids from kindergarten through high school. And, to help fire up the teachers' enthusiasm for science, they will get a chance to do some experiments themselves at Fermilab, Argonne National Laboratory, and other science centers around Chicago. A new institute, the Academy for Mathematics and Science Teachers, is being established on the campus of the Illinois Institute of Technology to run the effort.

Leon Lederman

Lederman, who is now science adviser to the governor of Illinois, first hatched the idea of such an academy 2 years ago as the result of a conversation with Energy Secretary James D. Watkins. A long-time advocate of getting the national labs involved in education, Watkins promised to help secure federal funds for such an initiative. Lederman then quickly convinced Mayor Richard Daley, Governor James Thompson, local schools, and science centers to support it.

His dream will finally take shape with the recent announcement from the Department of Energy that it will give the academy a $215,000 planning grant this year and $2 million next year. The National Science Foundation is also providing $200,000 to help get the venture off the ground. The academy will open its doors to the first batch of 50 teachers in December. When it is in full swing, it should have a staff of 100 and a budget of more than $30 million.

Some critics have argued that an academy to upgrade Chicago teaching should focus on reading rather than on science and math. But Lederman points to the crisis in science education, which remains in a dismal state 7 years after the 1983 "Nation at Risk" report warned that poor preparation in science and math among U.S. students will harm the nation's economic competitiveness. "What better place to start than Chicago, which has been called the worst school system in the country," says Lederman, who hopes the academy will emerge as a model that can be copied in the nation's largest 25 cities.

A lot of the credit for fleshing out Lederman's idea goes to Gordon Berry, an atomic physicist at Argonne who is on loan to the academy as acting director, pending the appointment of a permanent director by the academy's board of directors. Berry, together with the education staffs of Fermilab and Argonne, put together the academy's program. In addition to doing some hands-on science themselves, teachers will receive what the academy calls professional development once a week for 10 weeks from instructors experienced in using innovative teaching programs for science and math. Academy staff members will observe the teachers in their classrooms after they complete the program and offer them advice. The academy will also develop new instructional materials and work with local colleges and universities to help revamp teacher training programs.

A key objective, says Berry, is to teach children how to apply principles learned in science and mathematics to real-life situations. But the academy is facing a tough challenge in changing the real-life situation facing many Chicago schoolteachers. "Many teachers of elementary and secondary mathematics and science lack deep understanding of the content of their subject areas," says a report issued by Berry for the academy. "Underqualified teachers cannot be expected to inspire confidence, excitement, and competence in their students."

Lederman stresses that the involvement of scientists in the Chicago area will be critical to the academy's success. "It's the ultimate responsibility of scientists to train young people to ensure our future. And we'll be beating them with whips until they spend time at the academy," he added with a laugh. ■ MIN-WEI LEE

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