Freshman Chemistry Was Never Like This

To battle science illiteracy among college students, the New Liberal Arts program tries a fresh approach to teaching science

LARRY KAPLAN'S CHEMISTRY LAB was just getting under way when a campus security officer rushed in and announced there had been a hit-and-run accident behind the chemistry building. "Hold on," Kaplan told his students, "class isn't over yet. Bring your notebooks and follow me to the crime scene." It didn't take long for the class to figure out that the "accident" was a fake, but everyone played along. They called an ambulance for the "victim" (Kaplan's daughter), roped off the scene of the accident, and began collecting evidence. Their assignment: to identify the vehicle that supposedly hit the girl by comparing glass fragments found at the scene with glass samples taken from the headlights of the suspect's vehicle.

This is obviously not Chem. 101 with test tubes and balances and smelly chemicals. And that's precisely the point. Kaplan, chairman of the chemistry department at Williams College in Williamstown, Massachusetts, is one of a new breed of science teachers who are trying innovative curricula and novel classroom techniques to reach students who would otherwise never learn much science.

Science courses for nonmajors aren't new, of course. They've been around for decades in such classes as "physics for poets." But since 1983, when the Department of Education published "A Nation at Risk," warning of the "rising tide of mediocrity" in our schools, there has been a growing consensus that something drastic needs to be done to improve the science literacy of U.S. students. Now nearly every college and university can point to one or a few Larry Kaplans on its faculty, but most of the efforts have been scattered, performed by imaginative teachers working alone. One coordinated, multi-college project, however, has been quietly chipping away at the problem since 1982—the year before the education department brought it to the nation's attention.

The New Liberal Arts, a program funded by the Albert P. Sloan Foundation of New York City, has spent more than $20 million at three dozen liberal arts colleges to develop new ways to teach science to nonscience students. The results include Kaplan's chemistry course and more than 200 others, covering the gamut of disciplines from engineering to the physical, biological, and social sciences. And 2 weeks ago, 80 participants gathered at Trinity College in Hartford, Connecticut, to discuss their successes and failures in the NLA program. The lessons they have learned may well prove valuable to many other schools struggling to turn back the rising tide.

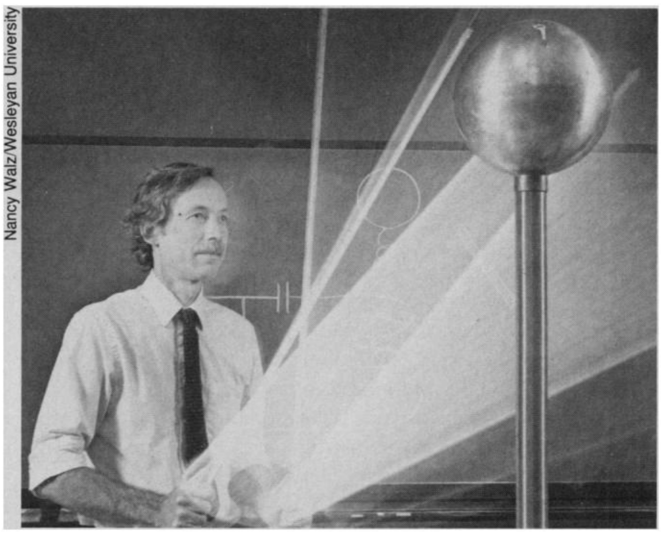
Kaplan's chemistry lab illustrates one of the basic themes that emerged from the NLA workshop: Science must be taught in a way that will catch the interest of the student. Esoteric vocabulary and mind-boggling formulas, no matter how essential they may seem to practitioners, will only scare away the liberal arts student who is already suspicious of science.

Kaplan draws his students in by talking about forensics. He discusses the admissibility of evidence, the importance of collecting appropriate controls, and how to analyze a crime scene. "All during this time, the students think they're not doing any chemistry," he says. "But what I'm really doing is teaching them about the scientific method, the importance of clearly identified samples, the use of controls and standards, and other aspects of doing good science."

And they get hands-on experience in the lab. They analyze the glass samples from the hit-and-run accident by measuring their density and refractive indices. In another session, they drink measured amounts of beer and correlate their breathalyzer readings with their alcohol consumption. The lab also includes plenty of the more traditional chemical analysis techniques, Kaplan says, but the experiments are always prompted by something from forensic science.

"The central theme [of the New Liberal Arts program] is the use of modern technology as a vehicle for motivating students and guiding them," says John Truxal of the State University of New York at Stony Brook, who is codirector of the NLA. This distinguishes the NLA curriculum from most of the traditional science-for-nonscientists courses. "Such courses are usually nonmathematical, watered-down versions of the normal introductory courses," Truxal points out, and as such they are poorly designed to promote scientific literacy. Introductory courses may give majors everything they need to continue on to more advanced classes, but a student who is only going to take one physics (or chemistry or biology or geology) course needs both much less and much more.

A nonscience student can actually be shown much more science in a single course than a science major since the nonmajor does not need all the groundwork for later courses, says physicist Ralph Baierlein at Wesleyan University in Middletown, Connecticut. Baierlein teaches a course called "Newton to Einstein: The Trail of Light." Students are fascinated, he says, by such concepts as wave-particle duality and special



Nancy Walz/Wesleyan University

May the force be with you. *Teacher Ralph Baierlein combats science illiteracy not with laser swords but with a demonstration of gas-filled tubes that glow in an electric field.*

relativity, which they would not come across until they were upperclassmen if they majored in physics. That fascination has made the course popular, Baierlein says. Expecting 20 to 30 students the first time he offered it, he got 141. The next year, 170 students signed up, including about 20% science and math majors.

To get the concepts across without equations and technical explanations, Baierlein gives plenty of classroom demonstrations. "It enables people to see things, to believe things," he explains. In one of his favorites, he holds a neon-filled tube in an electromagnetic field to show how excited atoms emit light. "That is so striking a demonstration that a picture of it actually showed up last year on the university calendar," he says.

A second physics-for-nonmajors course at

Wesleyan, "The Quantum World," has proved less successful, Baierlein says. The concepts from quantum mechanics fascinate the students, he says, but are too far above their heads. "It's like watching 'Star Trek'—it's fun, but I don't know how much they're learning." The moral: "You can't teach abstract algebra to fourth-grade kids. Some things just can't be done because the mind isn't ready for them."

Several teachers at the Trinity College meeting described making scientific concepts more understandable to students with the imaginative use of some common high-tech devices. Physicist Theodore Ducas at Wellesley College in Wellesley, Massachusetts, for instance, has harnessed the video camera to help students understand dynamics and the laws of motion. In one experiment, a student tosses an object in the air while another student films it, holding the camera steady. The students then run the film frame by frame and measure the position of the object as a function of time, which is given by the camera's frame rate. They can see for themselves that masses in a gravitational field really do move in a parabola, Ducas says, and also that their vertical velocity remains constant throughout the motion.

In a more whimsical demonstration, Ducas traveled in an elevator up and down 40 floors of Boston's Hancock Tower, standing on a scale and pointing a video camera at the readout between his feet. Playing the videotape to his class, he showed the students how to calculate the acceleration of the elevator based on the change in his weight, and with this to compute the elevator's speed and position.

"Half of the introductory physics labs at Wellesley, both for science and nonscience majors, are now based on AVID [Active Video Instructional Development]," Ducas says, and next he plans to extend the technique to teaching calculus.

Although the NLA courses do not emphasize solving equations, they do place a great deal of weight on developing "quantitative reasoning"—the ability to think in numerical terms and to make decisions involving probabilities and approximations. For example, Ducas confronts his students with the question of whether to perform amniocentesis on a fetus that might have Down's syndrome. Since the procedure slightly increases risk of miscarriage, the decision involves weighing various probabilities—how likely it is that the fetus carries the chromosomal abnormality for Down's syndrome versus the chance of amniocentesis causing a miscarriage, for example. "Our fundamental obligation is to teach students the skills to handle options," Ducas says. "This means that the students must, first, learn how to understand options and, second, develop skills in decision-making."

After 8 years of experience, the New Liberal Arts program is ready to share what it has learned with other colleges and universities, says Samuel Goldberg, NLA's program officer at the Sloan Foundation. Participants have published three textbooks based on NLA courses, with another nine planned. The foundation is also making available about 25 monographs on individual topics that can be integrated into existing courses and 25 extended syllabi for teachers who would like to pattern classes after some of the successful NLA programs. Interested faculty members can get copies free from Truxal at Stony Brook.

Unfortunately for the NLA, funding from the Sloan Foundation is coming to a close—the program will end in 1991. One of the topics at the Trinity meeting was where the money will come from to continue work on teaching science to nonscience students. Duncan McBride, a program director in the division of undergraduate science, engineering, and mathematics education at the National Science Foundation, says the NSF might fund some of it, especially cooperative efforts that involve teachers from a number of institutions. Although the NLA has developed some good courses, McBride says, a key question is whether other teachers at other institutions can adapt the material to their own settings. In addition to the NSF, Truxal suggests soliciting businesses for support: "I think corporate America has a tremendous stake in education, and we haven't even touched that resource."

■ **ROBERT POOL**

Teaching Science Appreciation

"This course is likely to be different from any science course you've had before," Robert Hazen told his students on the first day of class. "Most people aren't going to be scientists, and what we're trying to do instead of making you scientists is to make you people who can appreciate science." Drawing analogies with art and music appreciation courses and with sports, Hazen said, "Science appreciation is a lot like a sporting event. You don't have to be able to slam dunk to appreciate Magic Johnson."

Hazen's course, developed with colleague James Trefil at George Mason University in Fairfax, Virginia, revolves around "The Great Ideas in Science." It contrasts with the New Liberal Arts program, whose courses focus on specific, limited topics and use technology to draw students in (see p. 157). But both programs aim to combat the problem of science illiteracy among college nonscience majors. "The students we get come into the course both scared of science and unable to comprehend even the simplest newspaper article about science," says Hazen, who also works as a geophysicist at the Carnegie Institution of Washington. Now, after three semesters of teaching the course, Hazen and Trefil believe their approach is working.

The theme of the course is simple, Hazen says: "A small number of laws or concepts make up an overarching framework for everything that every scientist does." He and Trefil offer 18 of these great ideas, including "Everything is made of atoms," "The universe was born in a giant explosion and has been expanding ever since," "All living things are made from cells, the chemical factories of life," and "All life evolved by natural selection." Each concept is accompanied by specific examples that the students can relate to. When teaching about energy, for instance, Hazen and Trefil might discuss the moral and practical implications of using nuclear power.

Along with the great ideas of science, the two scientists also teach about the process of doing science—observation, forming hypotheses, and testing theories. Nor do they forget the personal side of science. In explaining the stereotypes of scientists, for instance, Hazen joked to his class that physicists are generally pictured with scruffy beards and T-shirts, chemists as wearing suits ("because they're all consulting for chemical companies"), and geologists are seen in flannel shirts and hiking boots. "The students come out with an understanding that science is a human process and that it deals with how the physical universe behaves."

Judging from student response, Hazen and Trefil have found a successful formula for teaching science to nonscience majors. Students at George Mason fill out detailed evaluations, and "they've been quite flattering," Hazen says. "Quite a number of students have said it's the best course they've ever had." Even more encouraging, he adds that "I've had students come up to me a year later and say that now they read the science section in newspapers." They probably still read the sports section first, but at least a few students have learned to appreciate science. ■ **R.P.**