Assault on the Lesson Plan

Courses are being revamped, and novel programs created, as U.S. science faculty try to capture the MTV generation

At Washington University in St. Louis, biologist George Johnson teaches a course on the biology of dinosaurs. His goal: To increase the interest of non-science majors in his favorite field. At the University of Wisconsin in Madison, chemistry professor Arthur Ellis is restructuring courses he had taught for 14 years to highlight the latest research in materials science. His objective: To show the chemists of tomorrow that the discipline's stodgy reputation doesn't preclude a chance to discover new vistas. And at Brandeis University in Waltham, Massachusetts, Lawrence Abbott teaches computer modeling of heartbeat rhythms and the progression of disease through a population (p. 869). His hope: To show even the most computer-illiterate undergrads that off-putting mathematical models can track real-world phenomena.

Across the United States, university science faculties are starting to realize that traditional curricula no longer do the job and that radical changes are needed in what and how undergraduate students are taught. Biology graduate students are being told to emulate medical-school students by rotating through research laboratories rather than remaining in one area for their entire graduate careers. Entire departments—such as the chemistry department at the University of Michigan—are reworking their offerings to make them fit together better. Traditional disciplines are recognizing that they must introduce other disciplines—for example, every physics major at the Massachusetts Institute of Technology must now take at least one introductory course in biology. And new communication channels—from electronic mail to annual conferences for innovators—are allowing would-be reformers to incorporate the successes and avoid the failures of others.

Indeed, big money is flowing into curricula reform, principally from the National Science Foundation (NSF) and the Howard Hughes Medical Institute (HHMI). Efforts to reform curricula and teaching methods in college-based science education received $18 million of NSF's $81-million budget last year for improving undergraduate education. HHMI has put $63.9 million over 5 years into reforming biology programs, including programs to help schools upgrade their teaching labs, and may spend even more next year.

But for reforms to succeed and spread to other schools, reform-minded faculty members must breach some formidable barriers. "There have been waves of reform efforts since the 1950s," says Arnold Arons, a professor emeritus of physics at the University of Washington in Seattle and veteran of past battles. "But the question is whether they can last." Few do, he believes. Why not? Arons and others point to such obstacles as tenure policies that promote faculty research over teaching, an unwillingness by faculty members to change how as well as what they teach, and resistance to reforms developed at other schools.

Facing facts

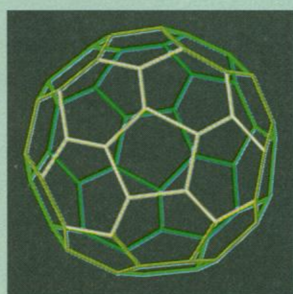
One hopeful sign of permanent change is the growing desire among faculty members to instill in students the critical thinking skills necessary for life as a scientist. "A lot of curricula just want you to memorize facts and repeat them on multiple-choice exams," says New York University neuroscientist Lynn Kiorpes, who heads NYU's new undergraduate neuroscience program. "But science is using what you know to solve a problem."

Science also must be more than a history lesson, says John Rigden, the director of physics programs at the American Institute of Physics. First-year physics courses taught as a chronology of the progress of physics from Newton's mechanics to Maxwell's electrodynamics and Einstein's relativity not only turn students off, he says, but they also rarely reach the present. The result, says Rigden, is that "a student taking introductory physics is left with a picture of physics in the 1880s. Yet we tell students that 20th-century physics is the most exciting part."

So what are reformers after? Says Linda Mantel, dean of faculty and a biology professor at Reed College in Portland, Oregon: "We want to devise ways to teach problem-solving skills to people who want to be problem solvers." To achieve this goal, reformers are abandoning "plug and chug" curricula that emphasize how to read problems, figure out which equation applies, plug in given variables, and churn out the correct answer. In their place are courses that boost students' critical thinking skills. At Dickinson College in Carlisle, Pennsylvania, physics professor Priscilla Laws allows students to investigate physics phenomena such as friction and momentum rather than listen to lectures. At Trinity University in San Antonio, Texas, computers permit histology students to go beyond simply identifying cells to investigating how they interact and

Innovative Curricula

Introducing undergrads to hot fields



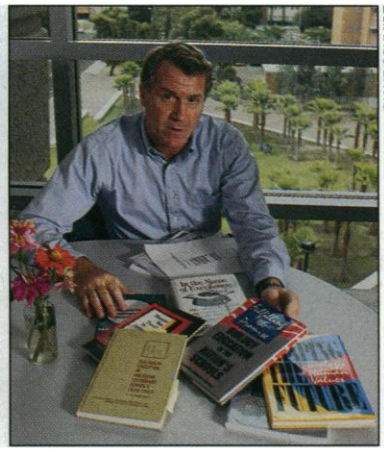
Developing interdisciplinary majors

Preparing for alternate career tracks

Encouraging undergrads to do hands-on research function. "These students are creating data sets on problems that have never been looked at before," says Trinity biology professor Robert Blystone.

Another common goal for reformers is to incorporate the latest research into the curriculum. Success can turn an introductory biology course replete with the dates of Darwin's voyages on the *HMS Beagle* into an exploration of how to manage an ecosystem to preserve biodiversity. "We want [students] to see right away how some of the courses they will be taking fit together to address everyday concerns," says Daniel Udovic, chair of the biology department at the University of Oregon, which recently added a series of freshman seminars on topics such as the biology of the timber crisis and the genetics revolution.

A. PIERCE BOUNDS



DIANE SCHMIDT

Actions, not words. Physicist Priscilla Laws *(left)* hopes to have a more lasting effect on students than the century's worth of curricula reform displayed by biologist Samuel Ward *(above)*.

Reformers are also placing renewed emphasis on interdisciplinary and interdepartmental courses to show students how several lines of research can be brought to bear on the same topic. At NYU, faculty members from seven departments joined 2 years ago to create a neuroscience major for undergraduates. Topics range from the molecular biology of synaptic communication between nerve cells to the behavioral aspects of neurological diseases such as schizophrenia and Alzheimer's. And at California State University, Los Angeles, students in ecology, chemistry, and biostatistics jointly study such environmental problems as toxicity levels of DDT in local fish.

At the same time students are learning how science relates to the real world, they are also getting a taste for the way science is practiced. "The hands-on work teaches them to think like scientists," says chemistry professor Leroy Wade of Whitman College in Walla Walla, Washington. Since 1978, the number of science undergraduates involved in research has jumped from a few percent to almost a quarter of those enrolled in science courses, says chemistry professor Michael Doyle of Trinity University, where every chemistry major is required to perform undergraduate research.

These changes are not confined to undergraduate courses. Graduate schools, in response to the long-running criticism that Ph.D.s are trained too narrowly, have begun to offer degrees in interdisciplinary fields, such as molecular and cellular biology and materials science, and to put greater emphasis on careers in industry. At the University of Texas at Dallas, for example, chemistry graduate students must complete a year-long practicum with local industry. And at North Carolina State University in Raleigh, scientists with as little as a master's degree are working with business grad students to form high-tech start-ups that can commercialize university research (p. 865).

Despite high hopes for such novel programs, critics warn that the lofty goals for reform have been sounded many times before. In a speech given last fall to directors of innovative programs, University of Arizona biologist Samuel Ward reminded his colleagues that the most common characteristic of curriculum reform efforts is amnesia. As proof, he hauled out three reports—spaced 30 years apart and spanning much of the century—all recommending such changes as boosting students' reasoning rather than memorization skills, harmonizing courses with everyday problems, and emphasizing future problems to be solved. Much to its chagrin, the audience was unable to date any of the reports.

Big hurdles

There are many reasons for the failure of curriculum reform, say critics, but the most obvious is a lack of money. The computer stations alone for an introductory physics course at Dickinson College called "Workshop Physics"—where students work together in groups of four—cost up to $2600 apiece. As many as 1300 students attend such introductory courses at large state universities, making the Dickinson model expensive to emulate. Even if the changes are affordable, there's no guarantee they'll become widely used, says Sheila Tobias, a social scientist who has written widely on science curriculum reform. "University professors value their autonomy as teachers," says Tobias. When Brandeis University faculty recently tried to integrate the school's biology, physics, and chemistry curricula, for example, consensus was elusive. "There are [faculty members] who think there is a logic to the current courses and that you just can't muck with it," says Brandeis University biologist John Lisman. The bottom line, says NSF's undergraduate education chief Robert Watson: "You can't tell faculty what to teach."

A final barrier to change is institutional. Opening labs to undergraduates requires that faculty spend more time with students. But there is little incentive to do so as long as faculty tenure continues to be based primarily on research achievements. "If the institutions ignore the reward system and don't support their faculty [who develop new science curricula], then faculty are likely to backslide," says Herb Levitan, NSF's head of undergraduate curriculum development.

Making changes stick

Faced with these obstacles, reformers downplay the likelihood of reforms spreading throughout the country's more than 3000 colleges and universities. "Systemic reform is not even the goal here," says NSF's Watson. Curricular change, he says, must begin in the hearts and minds of individual faculty members. Institutions can fund novel programs and spread information about what works, but that doesn't guarantee success. "You take the changes where you can," agrees Stephen Barkanic, who doles out curriculum development grant money for HHMI. "After a while, you hope

"We want to devise ways to teach problem-solving skills to people who want to be problem solvers."

—Linda Mantel

to see a lot of people making the same changes."

Although it is unlikely such grassroots movements will emerge simultaneously in all disciplines, there is good reason to expect modest improvements. In select disciplines, for example, broad-based faculty support for change already exists. A revised calculus curriculum that emphasizes concepts over equations is in the hands of roughly one quarter of the nation's 500,000 first-year calculus students. And "it's still picking up steam," says NSF's Spud Bradley, formerly associate executive director of the American Mathematical Society.

Chemistry reformers are also gearing up for a major overhaul. Last year, NSF received 112 requests for planning grants to overhaul chemistry curricula. And most of the 14 grants involved collaborations with as many as 10 colleges and universities apiece. To NSF chemistry program director Susan Hixon, the flood of proposals means just one thing: "The chemistry community is ready to change."

Of course, not all areas of the curricula are undergoing such sweeping change. In biology and physics, for example, reformers so far have focused on individual courses. In the past, such a piecemeal approach has tended to isolate reform-minded faculty even within their own departments. To discourage this scenario, funding sources like NSF and HHMI now actively solicit major research faculty and in many cases award curriculum reform grants to whole departments instead of individuals. At the University of Arizona, for example, researchers including Marty Hewlett, Richard Hallick, and Bill Grimes helped reform the school's introductory biology course to emphasize current research. And at Gettysburg College in Pennsylvania, biology professor Ralph Sorensen created a new biochemistry department featuring interdisciplinary courses such as molecular genetics. "These reforms can't just happen on the fringes," says Barkanic.

The word about reform is being spread by professional scientific societies and funding agencies. The American Chemical Society and the American Physical Society now regularly feature curriculum reform symposia at their annual meetings. At the recent American Physical Society meeting in Pittsburgh, for example, Dickinson's Laws was peppered with questions from dozens of her colleagues after a talk about her "Workshop Physics" course. And this year the American Society for Microbiology held a 1-day conference before its annual meeting to discuss curriculum development. NSF and HHMI are attempting to get the word out by bringing together those active in the reform movement. NSF also sponsors 15 regional summer workshops covering everything from new teaching techniques to the latest lab equipment.

With such outside support, many believe the current round of curriculum changes is here to stay. The most hopeful sign, believes HHMI's Barkanic, is a merging of innovative teaching and curricula. "You don't necessarily see all of the [solutions] happening in one department," he says, "but the awareness is growing that you have to move on a number of different problems at the same time."

However, awareness is only the first step. Unless faculty are given sufficient incentive to spend more time and effort on teaching, curriculum reform will remain the domain of the adventurous.

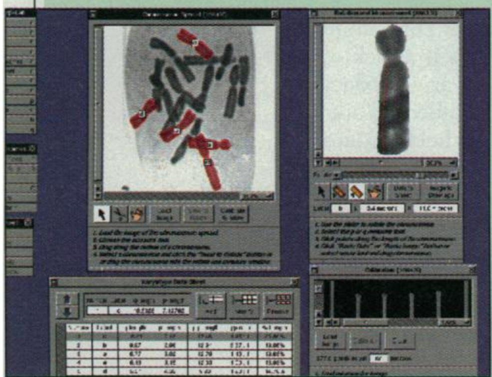
–Robert F. Service

Curricula Reform Hits the Web

Physics professor Laurence Marschall sees it every day. Someone logs on to his computer from a terminal hundreds or thousands of miles away, rifles through a set of files, and copies several computer tutorials that Marschall has written for his astronomy students at Gettysburg College in Pennsylvania. "It happens all the time," says Marschall. And he isn't the least bit upset. "It's good to see others are finding [the tutorials] useful," he says.

Welcome to the world of on-line curriculum reform. In the first 9 months since his six computer tutorials went on the Internet, more than 1000 people around the world obtained free copies of everything from calculating the mass of Jupiter to the rate of expansion of the universe.

Educators hope that the on-line revolution will help them clear a hurdle that has tripped up previous reform efforts: The ideas are good, but they don't reach enough people to bring about lasting change. For years, reformers have used electronic mail and list servers—electronic mailing lists for particular discussion groups—to communicate with one another and swap stories about their successes and failures. Now they are taking the next step—designing computer-based course materials and instruction manuals and making them available to anybody with a computer, modem, and access to the Internet.



Click and paste. Robert Desharnais' Karyotype helps beginning genetics students learn how to manipulate chromosomes.

On-line reforms aren't limited to astronomers, of course. At California State University at Los Angeles, biologist Robert Desharnais and geologist Gary Novak have created a set of computerized biology and geology labs available over the Internet. At Georgia State University, computer scientist Scott Owen has put a set of 20 computer-graphics education programs on the wires. And engineering professors Robert Caverly of the University of Massachusetts at Dartmouth and John Bourne of Vanderbilt University in Nashville, Tennessee, have done the same with engineering labs.

Although only a few handfuls of on-line courses are currently available over the net, the number is expected to increase rapidly in the next few years. Indeed, educators and publishers have started to worry about a time when the Internet might become like public-access cable television, clogged with programs that are mediocre or, even worse, filled with inaccuracies. "Quality control is really important, especially in science," says James Lichtenberg, vice president of the Association of American Publishers. Because publishers have traditionally played that role, Lichtenberg predicts that they will move into on-line course distribution as the field grows.

Such on-line alliances with academics are already in the making. Calculus reformers, led by Deborah Hughes-Hallett at the University of Arizona, are offering free electronic support materials to accompany their new textbook published by John Wiley and Sons. Liesl Gibson of Springer-Verlag in New York says the company is considering distributing free software as a way to trim the size and cost of some of its text and lab books.

The National Science Foundation (NSF) is encouraging reformers to build ties with publishers in an attempt to maintain quality without sacrificing quantity. William Haver, a former NSF program director now at Virginia Commonwealth University, can imagine an arrangement through which courses and lab tutorials are distributed free over the networks at the same time publishers sell companion materials such as student's and teacher's manuals. In the meantime, Marschall intends to keep distributing his tutorials for free and let his users gauge the quality for themselves.

–R. F. S.