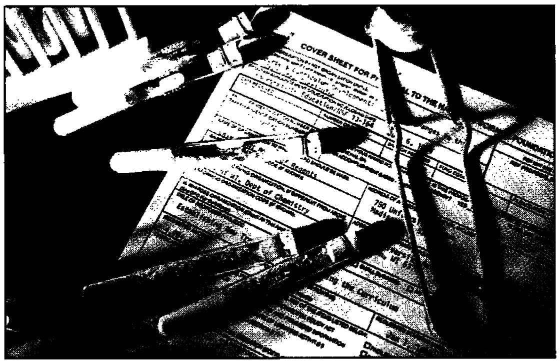
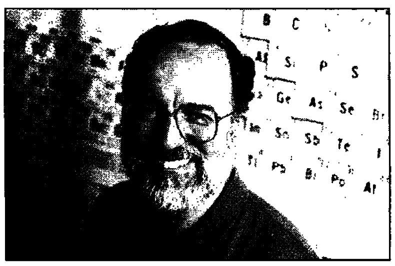
Novel Course II: 21st-Century Chemistry

One of John Moore's biggest frustrations with teaching undergraduate chemistry is that the lessons don't last. A 30-year classroom veteran now at the University of Wisconsin, Madison, Moore says: "The students go away for a summer and forget what we think we've taught them." So Moore fought back. Last June he submitted a sweeping proposal to the National Science Foundation (NSF) to create a new curriculum. Whatever NSF's verdict, Moore is committed to leading a coordinated effort between the University of Wisconsin and a handful of state universities, liberal arts colleges, and minority institutions in the East and Midwest to write a curriculum that will crystallize chemistry concepts in the minds of thousands of students. No more would newly acquired knowledge of acid-base reactions, phase changes, kinetics, and the like evaporate with the first summer breeze.

PHOTOS BY JEFF MILLER





Grand design. Not content to reform a single course, John Moore is trying to revamp all of undergraduate chemistry with his proposal to NSF.

Moore already knew that NSF was looking for radical curriculum reform. Last year, the foundation issued a Request for Proposals that dangled the prospect of a $10-million pot and individual grants of as much as $1 million. "We asked them to come up with a vision for systemic changes across curriculum," says Stanley Pine, then a NSF undergraduate education program officer. To underline his point, he added: "We want to change the whole thing, not just fiddle with a course here and there."

That's just what Moore's plan will do. Each of the schools within the consortium will experiment with a new approach, and a team of independent evaluators will figure out what worked, what didn't, and why. As a whole, the consortium will focus on five areas:

■ **Discovery-based and open-ended labs.** This idea, already in use at the College of the Holy Cross in Worcester, Massachusetts, reverses the usual sequence whereby students learn a concept in the classroom and reinforce it in a cookbook lab exercise. Instead, the lab experiments allow students to discover a concept and then learn more about it in the classroom. There will also be pilot studies in "open-ended" labs, where students define a problem and solve it using what they have previously learned. One class at Wisconsin was given techniques to measure hardness, oxygen levels, and the phosphate content of water. Groups then posed their own questions and designed experiments to answer them using water samples they collected. Moore says he hopes the approach will permit students to "experience the relevance of chemistry to their lives."

■ **Topic-oriented approach.** Professors at Wisconsin are starting to build courses around real-world topics to emphasize the relevance of the curriculum. For example, Clark Landis now begins his introductory chemistry course with a 3-week topical seminar, "Buckyballs, Diamonds, and Pencil Leads," that describes technologies associated with diamond film and buckyballs and explains the impact of structures on the properties of materials that share a common composition. Other topics under consideration are the ozone layer controversy and designer drugs.

■ **Use of information technology.** The group hopes to create software that would allow students to tailor courses to their interests and provide "interactive texts" on various topics, all interlinked through a program called hypertext. Students could view video clips of different chemical reactions, create and manipulate molecular structures, and calculate molecular properties. With the click of a mouse, students could change parameters of a reaction or other process.

■ **Better connections among disciplines.** Moore plans to coordinate chemistry classes with other science and mathematics courses to demonstrate the connections between disciplines. The goal is to prepare students to work on the interdisciplinary teams that carry out modern research projects. One approach would offer three-course clusters, such as math, chemistry, and engineering, that would focus on a common project or issue. The difficult part, says Moore, will be to convince faculty members to mold the courses into a coherent unit.

■ **Active/cooperative learning.** The goal of the reform efforts, says Moore, is to make the atmosphere supportive and noncompetitive without lowering standards. The consortium hopes to do this with group projects that reward cooperation.

Moore says a new curriculum will be cobbled together with the best of the various approaches. The final step, he says, could be a voluntary nationwide curriculum ready for students as they enter the next millennium.

–Faye Flam

Novel Course III: Undergrad Labs "Get Real"

Getting the chance to do lab experiments as an undergraduate didn't satisfy Pamela Fischer, who's winding up her doctoral program in chemical physics at the University of Oregon. Thinking back, she says, "usually you can complete a whole experiment in three-and-a-half hours."

What Fischer loved were the 10 weeks of sheer frustration she experienced as an undergraduate in a highly unusual lab course at the University of Oregon's Chemical Physics Institute. "In the CPI lab," recalls Fischer, "we saw all the quirks of doing new, exciting research. We actually had about one productive week, where we were getting spectra we could analyze. Research is not magic—you have to work at it, and you have to spend a lot of time thinking about the problem you're investigating."

Welcome to science education as conceived by Geraldine L. Richmond. A chemist, Richmond developed this unusual lab course about 7 years ago in response to a call for proposals from the National Science Foundation (NSF) for a new program entitled Research Experiences for Undergraduates (REU). "I already knew just how important genuine lab experiences were for keeping students in science," she says. But traditional labs, she notes, "are often designed so that the student is searching for a known answer. They can easily become boring and make the student feel like science is only about being a technician rather than about making discoveries."

Richmond's summer lab course is different. For one thing, she welcomes students with little hands-on lab experience because it only makes them more eager. "What the kids really want is to get in the lab and do things," says Tom Dyke, head of the University of Oregon's chemistry department and an REU participant. "So even though they may not be up to speed on such things as quantum mechanics, we've resisted the idea of giving them courses."

Another unusual facet of the 10-week course is that the research projects are real and can take as long as 7 years to complete. Relying on topics that require sophisticated lab equipment—high-speed lasers and high-resolution spectroscopes—the students cover anything from designing a hypothesis to wrestling with faulty lab equipment.

Students are also required to give an individual presentation about their part of the research at the end of the summer. "It's just like in graduate school, where there's a deadline, and the students feel that they can never possibly get the results they need, and they're up late the last night trying to get their talk ready," says Richmond. "But they always pull it off because they've been working and thinking hard."

When Richmond first proposed this notion, NSF was looking for professors like her who were willing to open their labs to undergraduates. But she wanted to place the lab in Oregon's then 8-year-old Chemical Physics Institute because she felt that operating a lab at the boundary between two major fields had major advantages. Explains Richmond: "We try to understand chemistry by using good physics—so it is intellectually very challenging. But the students who come here have typically never heard of our field: The whole idea of how important physics is to chemistry and vice versa is new to them. This overlap just opens up new worlds."

PHOTOS BY JACK LIU

Just do it. Oregon's Geraldine Richmond wants her students to do more than study chemistry from a book—she sends them out for a summer of lab experience.

This idea nearly cost Richmond her grant, thanks to the typical first reaction of funding agencies to multidisciplinary science. Neither the physics nor chemistry reviewers at NSF wanted to claim her project. "It did come close to falling between the cracks," says George Rubottom, an NSF program director in the chemistry division, which finally adopted it. What makes Rubottom so happy with NSF's role is his knowledge that, in its seventh year, Richmond's project is proof positive that genuine lab experiences do keep students' eyes on the graduate-school prize. Between 85% and 90% of those who have attended Richmond's summer lab have later entered doctoral programs, a figure that is 10 percentage points higher than the average for all recipients of these NSF undergrad research funds.

But despite her success, Richmond cautions other schools against mindlessly copying her effort. It is very demanding on a professor's time, she says. "Something like this should never be taken on lightly, because you can't just stick the kids in the labs; they need supervision and guidance." And her colleague, department chair Dyke, adds that there's generally no payoff in terms of "research output" because 10 weeks isn't long enough to obtain meaningful results.

Still, Dyke considers Richmond's brainchild an "excellent program, simply because it draws many students into chemical physics who may have gone into other fields. It's a very powerful recruiting tool." And as if that were not enough, the professors also get a charge from the students' enthusiasm. Says Richmond: "They are like a bright spark in the summer."

–Virginia Morell

Novel Course IV: Survival Skills 101

Michael Zigmond is tired of hearing excuses.

The University of Pittsburgh neuroscientist is fed up with shoddy overheads, illegible slides, and speakers who simply read their papers. "There's almost an ethic that it's not important to do a good job communicating science to our peers," he says. "What's viewed as the only matter of importance is the science itself."

Zigmond may be fed up, but he's not surprised. Few researchers receive any training in career craft, he points out. "We're just expected to know how to do all these things once we get a job." But rather than pointing fingers, Zigmond has begun treating the problem himself: He's teaching the art of making presentations—and a great deal more.

Zigmond's course, for graduate students and postdocs, is officially titled "Professional Development"; informally, it's "Survival Skills." Although not unique —similar courses are sprinkled across the United States, including at elite institutions such as Harvard University and the University of California, Berkeley—Zigmond's course contains features that make it stand out. For one thing, it's more practical: Zigmond will even discuss what printer fonts work best in a poster or grant application (bold for the title, serif for the body), on the theory that applicants need every edge in the fierce competition for funding and recognition. The Zigmond course is remarkably broad as well, including lectures on:

- Career opportunities in academia, government, and industry;
- The tools needed to land jobs, including interviewing techniques and negotiating skills;
- Writing scientific papers and grant applications;
- How to balance teaching and research loads;
- How to handle ethical quandaries; and
- Enhancing opportunities for women and minorities in science.

"We're trying to teach graduate students and postdocs all the things that those of us who have survived [in science] learned by trial and error," says Zigmond.

What do his clients say? "It's really improved how I come across in my talks," says Emory University's Meghan Burke, a former postdoc at Pitt. "I used to just