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EDUCATION

FOCUSING ON REFORM

NSF-funded innovations are slowly convincing faculty to change the way they teach chemistry

FOOD FOR THOUGHT **Beloit students extract fat from full-fat, low-fat, and no-fat potato chips--and learn chemistry along the way.**

AMANDA YARNELL

This fall, general chemistry students at Beloit College are exploring the fats--and fat substitutes--in our diet, learning about chemical notation, polarity, and thermochemistry along the way. Meanwhile, professors at Holy Cross College are asking their students whether the color of an aqueous solution of a metal cation depends on its position in the periodic table--and then letting them loose in the lab without recipe-like directions to find out why.

This is not how most of us learned chemistry. But educational research showing that students perform better when they are actively engaged in the learning process has led some educators to toss aside lectures, textbooks, and cookbook laboratory experiments in favor of one or more items off a menu of reforms offered by the National Science Foundation's Systemic Changes in the Undergraduate Chemistry Curriculum program.

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NSF'S DIVISION of Undergraduate Education (DUE) has been funding curriculum reform under the Chemistry Initiatives program since 1994. Grants totaling $14 million over five years were awarded to five consortia of colleges and universities--collectively involving more than 70 institutions.

Curriculum reform efforts born of these grants range from the relatively radical--scrapping the traditional structure of general chemistry in favor of a series of modules that use real-world questions to teach chemistry--to the more cautious: retaining the traditional lecture format but replacing recitation sessions with weekly small group sessions led by a student who recently completed the course. "But what all of these efforts have in common is a goal of actively engaging students in the learning process," says NSF's Susan H. Hixson, lead program director for the Chemistry Initiatives program.

The peer-led team learning (PLTL) project--a joint effort among 10 senior and community colleges at the City University of New York, St. Xavier University, the University of Pittsburgh, the University of Pennsylvania, and the University of Rochester--was spearheaded by David K. Gosser, a chemistry professor at CUNY's City College. Instead of jettisoning traditional lecture-based instruction, the PLTL model simply adds weekly two-hour workshops in which students "work together in small groups to obtain deeper understanding of material presented in lecture," Gosser says.

Under the guidance of a seasoned student veteran of the class, workshop participants work together to solve carefully structured problems related to lecture material. A good peer leader allows students to "take responsibility for their own learning," Gosser says.

In another consortium, John W. Moore, a chemistry professor at the University of Wisconsin, Madison, and editor of the *Journal of Chemical Education*, wanted to give his students a better grasp of chemistry concepts and to improve their long-term retention of the material. The result was New Traditions--a multi-institution project spanning Franklin & Marshall College; Holy Cross; the University of Illinois, Urbana-Champaign; San Jose State University; Madison Area Technical College; and Wisconsin. Instead of starting from scratch, the project sought to make existing innovations, such as guided-inquiry lab experiments like the metal ion color one being used at Holy Cross, accessible to a wide range of institutions--including those with big classes. New Traditions has also shown that a form of peer instruction in which students are asked to convince their fellow students of the correct answer to a question posed by the professor is amenable to large lecture classes. It also created a number of technology-based tools--including a Web-based lab skills

tutorial and a how-to video designed to help faculty use small group learning in large lectures--to improve the curriculum.

New Traditions, Moore stresses, produced materials that faculty could introduce relatively painlessly. But it was also intended to convince faculty, particularly at large schools like Wisconsin, that active learning is possible. "A common excuse for resisting teaching reform is 'It wouldn't work here,'" says G. Earl Peace Jr., a former lecturer in chemistry at Wisconsin who has since moved to Holy Cross. "New Traditions was designed to meet this reluctance."

"A common excuse for resisting teaching reform is 'It wouldn't work here.'"

THE MOLECULAR SCIENCE project, initiated by Orville L. Chapman and Arlene A. Russell of the University of California, Los Angeles, also included California State University, Fullerton; Crossroads School for Arts & Sciences, Santa Monica; Mt. San Antonio College; and Pasadena City College. The project created Web-based assignments called Explorations that allow students to study spectroscopic data and to visualize molecular models at their own pace. But the star attraction, Calibrated Peer Review, is a Web-based instructional tool that helps students learn chemistry by writing about topics like the photochemistry of suntans and sunburns. Students are then taught to critique essays and asked to review both their peers' and their own essays. Regular use of Calibrated Peer Review, Russell says, "teaches students to articulate chemical concepts coherently and to critically evaluate both their peers' and their own work."

Two other consortia came to the NSF with similar proposals to use topical modules employing active and collaborative learning strategies to teach chemistry. NSF funded both of them but requested that the two groups work together. ChemLinks is a joint effort led by Beloit's Brock Spencer that includes 15 midwestern colleges and universities including Beloit and Grinnell College. And Modular Chemistry Consortium is run by a group of California schools including UC Berkeley and was headed up by Berkeley's Angelica Stacy.

What emerged was ChemConnections: two- to four-week modules that introduce real-world problems, such as the amount of fat in our diets, global warming, and acid rain, and then help students develop the chemical knowledge and skills to address the issues. Instead of traditional lectures and cookbook labs, the modules rely on "hands-on" and collaborative activities as well as guided-inquiry labs.

What drove both projects, Spencer says, was "that students need to understand why chemistry is useful and important, and they want to know what it's going to do for them." Although the modules were designed to be used as an entire course, Spencer points out that many instructors choose to use just one as a theme for their traditional course.

MODEL STUDENT **Peer leader and City College undergraduate Gloria Rodriguez (right) helps her fellow students explore chemical structure.**

NOT EVERY ATTEMPT to reform the chemistry curriculum is guaranteed success, as Duke University's recent experience shows (C&EN, Aug. 26, page 31). But proponents of Chemistry Initiatives are quick to point out their successes.

Students participating in PLTL get better grades than those who are assigned to a traditional recitation section, Gosser says. But it's not just the students who benefit: The peer leaders learn valuable leadership skills, and many are inspired to teach--15 of CUNY's best peer leaders have gone on to careers in the New York City public school system, he adds.

According to Peace, Wisconsin students in general or organic chemistry New Traditions classes didn't do any better or worse than those in traditional classes on the American Chemical Society's standard exams. But student retention in both general and organic chemistry was significantly higher in the New Traditions sections.

Assessments of the Molecular Science project show that students who use the Web-based Explorations tool boast better comprehension of content than those who don't. Students who use the Calibrated Peer Review tool perform better on both multiple choice and essay exams, Russell says, suggesting that they are not only learning to write better but are also mastering content.

At both Grinnell and Berkeley, where careful evaluations were carried out, students in modular and traditional sections performed indistinguishably on standard ACS exams. But at both schools, students in modular sections did better at scientific problem solving and on tests of key chemistry concepts. And at Berkeley, general chemistry students in modular sections outperformed their traditional-section peers on the subsequent organic chemistry midterm exam.

Student reactions, however, were mixed: At Grinnell, modular

students were more positive about chemistry and the course than their traditional peers. But at Berkeley, where the modular course was still in its infancy, the situation was reversed. In a subsequent iteration of the modular course at Berkeley, students' attitudes about the course and chemistry were about the same as those in the traditional course.

But the initiatives' greatest success is "keeping the focus on reform," NSF's Hixson says. Sylvia Ware, head of ACS's Education Division, notes that although the initiatives have not made the dramatic changes in course content she had hoped for, they "have gone a long way toward bringing active learning into the classroom."

GETTING THE WORD OUT about the initiatives' successes has proved to be the biggest stumbling block. The original grants funding the four initiatives expired in 2000. Since then, grantees' energies and NSF's dollars have been funneled into getting other educators to use the innovations that have emerged. In 1998–99, NSF gave out some $1.4 million to educators to "adapt and adopt" these innovations, and the agency continues to give additional awards. And in 2000, the agency awarded a three-year, $1.1 million-dollar multi-initiative dissemination grant to fund workshop series and symposia at which interested faculty can learn how to use the tools and methodologies produced by the initiatives.

The free workshops, which take place all across the country, last a day and a half and expose faculty to each of the four initiatives, as well as update them on the latest in research about teaching, learning, and assessment.

According to Berkeley's Eileen L. Lewis, who heads the dissemination grant, people are coming to the workshops and taking the projects home. But the initiatives are certainly not sweeping the nation, and most of the people adopting them are those who were experimenting with reform in their own classrooms already. "We are selling our reforms at meetings where people have come to learn about education," Gosser adds. "So there's a natural preselection of our audience."

The real challenge, Lewis agrees, is to reach out to those not currently keyed into curriculum reform. "Most of us prefer to teach the way we were taught," New Traditions' Peace says. "And there isn't a large cohort of educators who were taught in the active learning style--at least not yet." Until such a critical mass builds up, convincing faculty to use the tools developed by NSF's Chemistry Initiatives is likely to remain slow going.

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