University of Alabama undergraduate Alice Boone tests soil samples from an oil-contaminated site near campus. As part of her inquiry-based coursework, Boone is looking for signs of bacterial diversity in the soil samples.
Photo: Alice Wilson

LEARNING TO LEARN

Undergraduates explore new ways to understand science

By Susan Perry

When Alice Boone looked over the course options for her sophomore year at the University of Alabama, she was intrigued by a new science course called "Introduction to Inquiry." Billed as a "discovery-based" class, it promised to give students experience solving real scientific problems.

"It wasn't presented like a regular science class where you memorize everything, take a test and move on to the next idea," recalls Boone. "This was hands-on. It was like real science."

So Boone signed up—one of seven adventurous students willing to give the innovative approach to teaching and learning science a try. She wasn't disappointed.

"The things that I learned in that class—the concepts and theories—stuck better because I had to actually go out and find them out for myself," she says.

At the University of Delaware (UD), 750 miles away, senior John Dueber enjoyed a similar learning experience in his final "problem-based learning" (PBL) course, "Intermediary Metabolism." The course is one of several at UD that challenge teams of students to investigate complex, real-world problems. Dueber says that the class, like other PBL classes he took during his undergraduate years, taught him more than just "background material"—the kind of information he might forget soon after handing in an exam. Instead, the courses taught him how to work collaboratively with others to solve scientific problems, forging "the same skills one has to use in everyday life," he says.

Although many undergraduate science classes continue to be taught in a traditional, lecture-based format, a growing

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number of colleges and universities are experimenting with active and collaborative learning. (HHMI supports both "Introduction to Inquiry" at the University of Alabama and several PBL courses at the University of Delaware, with grants from its Undergraduate Biological Sciences Education Program.)

Whether termed "discovery-based," "problem-based," or even "student-based," these classes rest on the same principle: motivating students to go beyond memorizing facts to develop a deeper knowledge of the material. In such classes, students work in small groups on real problems, learning to analyze, do research, think independently, arrive at conclusions and defend their positions. *(Problem-Based Learning in Practice)*

Reprinted from the July 2000 *HHMI Bulletin*, Vol. 13, No. 1, pp. 24-29.

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LEARNING TO LEARN 2

A Medical School Model

At the University of Delaware, professor Harold B. White III wants his students to learnhow to solve scientific problems in a new way—actively and collaboratively. Photo: Paul Fetters

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While PBL may be new to undergraduate science students, the method has been around for some time. The first courses were developed some 30 years ago at several medical schools, led by McMaster University in Ontario, Canada.

"Medical students were going into these large lecture halls where a series of physician-educators would march through every two weeks, tell everything they knew, and expect the students to assimilate it all and regurgitate it on an exam. It was very deadening," says Harold B. White III, a University of Delaware professor of chemistry and biochemistry and program director for HHMI's grant there.

Several medical schools, trying a new approach, built a curriculum around interesting medical case studies, White says. Groups of students guided by a physician/tutor analyzed each case study, trying to unravel symptoms and other clues to determine what was wrong with the patient and what the proper treatment might be. Along the way, the students found themselves learning physiology, anatomy, pharmacology and more.

"The problem essentially came first, and the student's learning was driven by wanting to know more," says White. This reversed conventional instruction, he points out. "Normally, you start with a textbook; you give all the theories and concepts and then you do the problem," he says. "Very often students don't see the relevance of what you're doing."

White and other UD science professors became interested in PBL methods after attending a workshop about seven years ago on medical schools' experiences. "Several of us had an epiphany of sorts," he says. "We said, 'Wow, this is what's missing in undergraduate education as well!'"

A National Science Foundation grant helped them introduce problem-based learning in UD's introductory undergraduate science courses in January 1994. Other grants, including HHMI's, enabled them to expand the program to include student tutor–facilitators in PBL classrooms.

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Overcoming Resistance

Teams of University of Delaware undergraduates work on problem-based learning assignments.
Photo: Paul Fetters

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Winning students and faculty over to the PBL approach wasn't easy. "Problem-based learning is unfamiliar, and it takes time and effort to implement," White says.

For students, problem-based learning means that a professor no longer spoon-feeds them information. "There are some students, often very good students, who are used to sitting in lectures, gathering information," says White. "Suddenly the teacher is saying, 'I'm not going to give you the answer even though I know it. You're supposed to go out and find the answer.' Of course, that means extra work. It's frustrating to some students to learn that way. But in the long run, this is what they need to learn how to do."

Former UD student John Dueber agrees, although he admits that he felt hesitant about taking his first PBL class, "Introduction to Biochemistry."

"I hadn't had any previous classes in biochemistry and felt that this wouldn't be a good way of learning background material," says Dueber. He found that he experienced considerable growing pains during the course. "This style of learning requires a large amount of time, especially at first, and I had a very busy schedule. I was sometimes frustrated with how little gain I was making, but gradually I became better at using the resources around me and started to feel that I was making progress," he recalls.

He wound up enjoying the PBL course so much that he signed up for others and even served as a student–tutor for a PBL class during his junior year. He believes his experiences helped prepare him for his current graduate work in biochemistry at the University of California, San Francisco. By undertaking PBL coursework "with the right attitude, one can really learn—and more importantly remember—a tremendous amount," he says.

Professors, too, often find problem-based learning a bit disorienting at first. "It involves a different mindset that some have described as being a 'guide on the side' rather than a 'sage on the stage,'" says White.

In addition to knocking the professor off his or her pedestal, the method presents logistical problems. In introductory courses, for example, dividing a large class into small groups—an essential element of problem-based learning—can present a major organizational and management challenge. White uses student tutor–facilitators

to tackle the problem. The students are not experts in the subject being taught, but they are familiar with the PBL approach and receive training on how to facilitate group work and keep it on track.

Another stumbling block for some teachers is the effort it takes to develop problems for their PBL courses. Although White says he enjoys writing problems because of the scholarship and creativity involved, he knows that others may not. To help, he and other UD faculty are developing a Web page where teachers can share PBL problems.

Despite his enthusiasm for problem-based learning, White does not think it is the only way to teach science. "I think that a curriculum based solely on a problem-based format is as inappropriate as a curriculum based entirely on lectures," he says. "Because good students learn best in different ways, they should be exposed to a variety of learning experiences, including problem-based learning."

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LEARNING TO LEARN 4

No More "Cookbook" Labs

Martha Powell, chair of biological sciences at the University of Alabama, introduced inquiry-based learning to generate an enthusiasm for problem solving amoung her student teams.
Photo: Alice Wilson

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At the University of Alabama (UA), educators aimed to expand students' learning experiences in the discovery-based course, "Introduction to Inquiry." Martha Powell, who became chair of UA's department of biological sciences in 1997, created the course, which was first offered in 1998. Powell wanted students to experience something other than the standard "cookbook" science labs. That kind of lab, she believes, "teaches certain skills, but doesn't teach the big inquiry approach to science. And it's not exciting. It really doesn't portray how we do science, because as scientists we work in teams."

Powell doesn't want students to ask, "Did I get the right answer?," but rather to say, "This is the answer I got," and then critically appraise that answer.

Students work in small teams on real-world problems. For example, sophomore Alice Boone's team studied soil from an oil-contaminated site near the university to determine if the contamination had decreased bacterial diversity. The students gathered soil from the site, extracted DNA and examined it for bacterial diversity. Then they compared those samples with samples from noncontaminated soil.

"We found that diversity actually was increased in the oil-contaminated samples," says Boone. "That was a surprise."

After each team gathers data, members analyze their results and present their findings to the rest of the class. If teams come up with contradictory findings, lively discussion ensues—just the kind of active collaboration and learning Powell wants the class to engender.

"We had to explain [our findings] to the class as if we were talking to people who knew nothing," says Boone. Each student also had to write up the results in a standard scientific research paper.

For Alice Boone, an unexpected bonus was the close relationships she developed with her "Introduction to Inquiry" professors. "The teachers were more real to us," she says. "It wasn't as if they were people we just couldn't talk to. It seemed like they cared more about us personally and were more willing to guide us along and tell us things we actually need to know out in the world."

This spring, UA is offering a second discovery-based course,

"Integrated Genetics," and more may follow. Powell and her colleagues are also developing a booklet on discovery-based learning to help teachers at other institutions develop similar courses.

Boone, who intends to go on to earn a doctorate in microbiology, enthusiastically recommends "Introduction to Inquiry" to her friends. For her, the course turned out to be "a totally different learning experience," one that she believes will make her a better scientist.

"I ask more questions now," she says. "I don't just remember what I learned in class and then spit it back out. I actually, truly understand what is going on."

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