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Biology Examples Give MIT Students a New Perspective on Chemistry

When Allison Hamilos came to the Massachusetts Institute of Technology last year, she dreaded having to take the mandatory general chemistry course for freshmen. Eyeing a future in medicine, she couldn't see much point in learning chemistry.

"I didn't like chemistry at all in high school," says Hamilos, now a sophomore. "I was really surprised to find out how much I liked it in college and how relevant it is to biology. (It) has been my favorite class at MIT so far."

That's exactly what Hamilos's teacher, HHMI Professor Catherine Drennan, had in mind when she infused her introductory chemistry lectures with examples from biology and medicine. "I have been totally amazed by the huge impact this small change has made in terms of the students' attitude about the connections between biology and chemistry," Drennan says. "They really see that chemistry is the heart of biology and that is a big change."

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- Catherine L. Drennan

This relatively simple approach generated an enthusiasm and an improved appreciation for chemistry that was so significant Drennan and her colleagues published the results in the December issue of the journal *ACS Chemical Biology*. She hopes that success can be replicated in chemistry classes across the country.

The full curriculum can be found on MIT's web site at <http://ocw.mit.edu/OcwWeb/Chemistry/5-111Fall-2008/BiologyTopics/index.htm>. The link is also available in HHMI's Cool Science for Educators site.

While scientific research increasingly takes place at the interface of disciplines, most undergraduate classes are still taught within the confines of traditional science fields: physics, chemistry, biology. As a result, students often view disciplines as separate and unrelated. That is true for the roughly 200 students in MIT 5.111 or Principles of Chemical Science, the introductory chemistry class that Drennan teaches. It's intended for students who have taken high school chemistry – but may lack a strong background in the subject – and so it tends to attract students who are not interested in chemistry or those who think that they are not good at it.

Drennan, a chemist who has long been interested in education, decided to use part of the \$1 million grant she received as an HHMI Professor to change that perception among a subset of MIT students. Drennan and co-instructor, Elizabeth Vogel Taylor, who received a Ph.D. in bioorganic chemistry at MIT, developed examples based on biological and medical topics that demonstrate basic chemical principles. “I wanted to do something that anyone could replicate with a minimal amount of effort,” says Drennan, who has since been named an HHMI investigator. “If you really want to affect change, it needs to start at a level where it is practical and easy to do.”

The examples and problem sets link specific chemistry lecture topics to biology. One example is electron exchange of oxidation/reduction reactions, a common introductory chemistry topic, and its link to the activation of vitamin B12 in the body. Hamilos' favorite example relates to the wave-particle duality of light and matter, which Drennan and Taylor explained through quantum dot nanoparticles, small semiconductors that emit light when excited by UV radiation. They then showed how quantum dots can be used to help create images of tumors.

The teaching team used clickers—handheld electronic devices that let students respond to questions posed by professors in real time—to make some of the biology examples interactive. The instructors would propose problems for the students to solve during class and offer multiple answers. The students answered the questions using the clickers, and the results were displayed immediately on the overhead projector. This gave Drennan and Taylor immediate feedback on what percentage of the students understood the concepts and which students still needed help. “It allowed us to see if students were understanding the (biology) concepts and adjust if we needed to,” Taylor says. “It also kept the students engaged.”

Drennan and Taylor enlisted Rudy Mitchell, an educational researcher from MIT's Teaching and Learning Laboratory, to help them assess whether the students learned anything different from the biology examples. Mitchell developed a survey that the introductory chemistry students completed at the end of the course, in addition to the standard end of course evaluations.

The researchers compared students who took the class from Drennan and Taylor during three different years: 2006, when the class contained no biology examples; 2007, when only half of the course contained biology

examples; and 2008, when the entire course included biology examples.

The standard year-end course evaluations showed a statistically significant increase from 2006 to 2008 in three areas -- the number of students who were satisfied with the course; the number of students who claimed the course inspired interest in chemistry; and the total number of students who said the course used good examples. Of the students who were exposed to the biology examples, 86 percent reported that the examples helped them to see the connection between biology and chemistry.

“Even more interesting was the student attendance in the course,” Mitchell says. “Large lecture classes often suffer from poor attendance. But 85 percent of students reported attending 90 percent or more of the lectures. That’s unheard of in a lecture with 200 students, and it speaks to how enthusiastic the students are about the course.”

Mitchell noted that students viewed the experience very positively, describing it as meaningful, effective, enjoyable, supportive, motivating, and challenging.

Her student’s perception of this class is important to Drennan because she sees herself in her chemistry-avoiding students. “I had taken chemistry in high school and hated it. So when I was told I had to take chemistry I wasn’t happy at all. But (I) fell in love with it,” she says. “I almost missed out entirely. My life would have been very, very different if the person teaching that course hadn’t been able to reach me.”

Drennan discovered that many of the MIT freshmen she encountered harbored similar reservations about chemistry. “I talk quite openly about it in class,” she says. “I tell my students, you may not have discovered your love for chemistry yet, but I’m going to show you how it is applicable.” She hopes that by showing her students how chemistry is related to other disciplines she can help them become better doctors or engineers or maybe even chemists. She has at least made one student look at her life choices.

“I’m actually considering choosing chemistry as a major now,” Hamilos says. “I would have never predicted that!”