Involving Students in Antibiotic Discovery

Involving his students in Tiny Earth, a worldwide network of instructors and students focused on crowdsourcing antibiotic discovery from soil, made sense to Tom Martinez, biotechnology and Advanced Placement Biology teacher at Glenbard East High School in Lombard, Illinois. "Having students participate in real science that contributes to the greater good" is important, and Tiny Earth supports the *Next Generation Science Standards* (*NGSS*), he observes.

Jo Handelsman—a professor in the Department of Plant Pathology at the University of Wisconsin (UW)-Madison and director of the Wisconsin Institute for Discovery, a research institute on the university's campus—founded Tiny Earth (*https://tinyearth.wisc.edu*) in 2012 at Yale University. Based on her work in antibiotic discovery there, she created an undergraduate introductory biology course called Microbes to Molecules, which aimed to address antibiotic shortages and the need for more scientists, and piloted the curriculum with six students.

"We're losing antibiotics every year due to resistance among pathogens. Pharma stopped discovering them in the 1980s because antibiotics became less lucrative than other types of drugs [for companies]," she explains. "We have more untreatable bacterial infections. By 2050, it will be the leading cause of death worldwide."

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Enid Gonzalez-Orta, associate professor of biological sciences at Sacramento State University in Sacramento, California, examines bacterial colonies during a Tiny Earth Partner Instructor training workshop.

Because antibiotic resistance is "a very real problem, students feel like they're contributing to science that will affect human welfare," she contends. As a result, the Microbes to Molecules course became popular, and Handelsman and her colleagues gradually developed it into a larger initiative. When she moved to UW-Madison, she established Tiny Earth there and built it into a network of instructors worldwide. Now nearly 10,000 students are enrolled in some version of the course annually in 45 U.S. states and 15 countries.

Tiny Earth is also necessary because studies have shown "we don't retain students who are really excited about careers in science," says Sam Rikkers, Tiny Earth's executive director. "About 60% of students [who] intend to major in STEM…graduate in a non-STEM field." Tiny Earth is effective because "instead of replicating old experiments, students conduct their own research, and their research is part of a global effort to find new antibiotics," he asserts.

Tiny Earth is "a way to teach what researchers do in science," Handelsman observes. In addition, the course is "not just memorizing organisms, plant parts, or long lists of terms. Research turns this around and gets students motivated to learn the facts because of the problem they are solving."

Tiny Earth Partner Instructor training sessions are held twice annually for high school and undergraduate instructors. "We are committed to making it as accessible as possible. We raise funds from partners and sponsors. Interested teachers just have to pay for their travel: Everything else is covered, free of charge," Rikkers explains.

"If teachers can't get a particular technique to work, they can use the Tiny Earth network to troubleshoot [the problem]," notes Handelsman. "Once trained, we set [teachers] up with a mentor trained by us."

The course can be implemented in a variety of ways, Rikkers points out. Tiny Earth can be a summer course, "a stand-alone elective," or "integrated into Introduction to Microbiology or biology courses," for example, he relates.

Teaching the Course

High school teacher Martinez does Tiny Earth in his classes twice a year. "We talk about antibiotic resistance in our curriculum," he notes, so Tiny Earth helps students "get a real understanding of the issue."

Martinez says he enjoyed the Tiny Earth training, but found it challenging. Though he was already familiar with gram staining (a technique used to differentiate two large groups of bacteria based on their different cell wall constituents), "I hadn't seen all the other techniques [demonstrated because] I hadn't had microbiology in a long time. All the techniques and protocols were new to me," he relates.

He faced other challenges. Unlike university instructors, Martinez says he has "only 48 minutes to set up [the lab] each day," so he has had to adapt what he learned during training to his high school classes. And he estimates that Tiny Earth involves "a $2,000 investment up front for consumables and sequencing [of antibiotic-producing isolates] costs…My district funds me because [Tiny Earth] has a lot of meaning [for students], and without the funds, I couldn't do it."

Safety issues must be considered, he stresses. "You never know what you'll find in the soil. Students have to be conscious of pathogens in soil." When growing bacteria in specific media, "we use ethanol and spray everything down with it…we wear gloves, goggles, and lab coats. There's an element of risk; most high school students aren't aware of this," he contends.

As a result, he says his students "looked at soil in a new way…They had a whole new perspective on food safety, for example, and sanitation." They also learned new skills, such as "plating and using parafilm [thermoplastic material manufactured for wrapping and sealing]," and how to use equipment, such as a Bunsen burner.

Lucy Fenzl, biology instructor at College of the Menominee Nation—which has campuses in Green Bay and Keshena, Wisconsin—incorporated Tiny Earth in her general biology and microbiology courses at both campuses. She says Tiny Earth's "lab techniques drew me to it. [It has] some really unique lab techniques that could expand research opportunities for students." She also received training in chemical analysis, which was a new skill for her. "These techniques can also be used in chemistry courses," she notes.

Tiny Earth "enhanced students' critical-thinking skills; they developed new ways to [conduct research]," Fenzl explains. For example, using the Phenology trail on the Keshena campus, students collect data from 13 different plants to study climate change. They've taken soil samples at each plant site as part of their Tiny Earth work. "I'll take the soil data and add it to the climate change data on the trail," she reports.

In addition, the opportunities to connect with other colleges and universities "took our research to a whole new level," Fenzl asserts. "Students can see and analyze results immediately and connect [their results] with all of the other [Tiny Earth] schools in real time." A nearby college in the Tiny Earth network "let us have freezer space because our freezer doesn't go to [a] temperature that is low enough [for a particular project]," she adds.

A Tiny Earth symposium held in December 2018 in Green Bay "gave students the opportunity to network with other student researchers, sponsors, and future employers to see what other students were looking at, ideas for future research," Fenzl relates. ●