CURRICULUM

Teaching Science So It Sticks

Amanda L. Smith for The Chronicle

On the first day of class in his astronomy course at the U. of Oregon, Scott Fisher tells students he's not out to recruit majors; he wants them simply to have a positive experience with science. "You can just see them physically relax," he says.

By Dan Berrett | MAY 04, 2015 ✔ PREMIUM

EUGENE, ORE.

Scott Fisher gets a lot of educational mileage from a postcard.

Each quarter Mr. Fisher, a lecturer in astronomy at the University of Oregon, asks students in his introductory course to write to him at his cosmic address. That means not only including his room number here in Willamette Hall and his ZIP code, 97403, but also locating him in the universe.

The extra-credit assignment serves one of Mr. Fisher's main goals for the course: helping students develop a sense of scale, or what he calls "a cosmic perspective." Along the way, he hopes to firm up their tenuous grasp of scientific reasoning and make them more comfortable with science. That's the idea behind several revamped courses in biology, chemistry, geology, and physics at Oregon, to raise an often paltry level of science literacy among nonmajors.

The approach aligns with efforts nationwide to improve science education, though not only to produce more graduates in science, technology, engineering, and mathematics, the STEM fields. Programs like Oregon's recognize an equally important but less heralded need: for the vast majority of students, who will never major in the natural and physical sciences, to gain some understanding or appreciation of those subjects.

It's a low bar but still hard to reach. The paradox reflects the shaky scientific knowledge that many students bring to college and their insecurity about disciplines haloed in exceptionalism. Rates of scientific literacy among American adults hover below 30 percent. More than a third of them aren't convinced that the planet is warming, and only half think human activity is causing climate change, despite consensus among scientists that it is.

Even long-settled subjects are still clouded by doubt: 30 percent of Americans say parents should be able to choose not to vaccinate their children; 53 percent think humans and dinosaurs coexisted; and 70 percent don't believe in the Big Bang theory. Given the social and political stakes of urgent scientific questions, educators are hoping they can help produce a citizenry more adept at science.

Mr. Fisher tries to build his students' knowledge, in part, by making astronomy approachable. In a class this past fall, he read aloud the addresses on students' postcards, looking for the most scientifically accurate, clever, and creative one. He lavished the winner with geek swag: patches and stickers from the Gemini Observatory in Hawaii, where he'd spent nearly a decade doing research and public outreach.

The astronomer drew special attention to a postcard that arrived in the current batch, from a student who'd taken his course the previous year. By then a graduate living in France, he said he'd read a news story about the discovery of the Laniakea system, a densely packed group of galaxies called a supercluster, which includes the Milky Way. So he included it in the address.

"A year later," Mr. Fisher said, "we have a normal person, not a physics major but a normal person, who thought about the Laniakea system."

He beamed. "This," he said, "is winning."

The notion that success can mean producing graduates who follow science news after college shows how baffling and intimidating many students find the subject.

Reinforcing their discomfort are widely accepted assumptions that would be heretical elsewhere in academe: that many otherwise intelligent, capable people simply don't have what it takes to learn science (or math) — and that it's OK if they never do. General-education requirements can perpetuate that thinking: Science majors take rigorous entry-level courses. Everyone else gets "Rocks for Jocks."

It doesn't have to be that way. Scientific reasoning — observing, hypothesizing, experimenting, evaluating evidence — is a staple of childhood. Kids are eager to test, say, the explosive properties of a breath mint dropped into a soda bottle. But something changes. Curricular convention in schools often restricts serious science courses to students who excel in math. Or science teaching is weak at all levels. Also, instruction must contend with the rapid advancement of scientific knowledge, which doubles every nine years, by one estimate. Eventually the child's impulse to explore and wonder shrivels before a wall of arcana.

The Soviet launch of *Sputnik,* in 1957, and the National Defense Education Act, a year later, marked a symbolic moment, says Rush D. Holt Jr., chief executive of the American Association for the Advancement of Science. Long viewed as widely accessible and valuable, science became rarefied. To produce a generation of scientists and engineers who would

drive American innovation and secure the nation's superpower status, colleges designed introductory courses as weeding mechanisms. High attrition in the classroom was a badge of honor for professors. They were upholding rigor, grooming tomorrow's experts.

The model served its purpose but produced unintended consequences. "We left behind 80 percent of the students," Mr. Holt says. "I don't think that was wise."

A physicist who served eight terms in Congress, he sees the legacy of that shift in public attitudes. "Appreciation of and support for science is eroding," he says, and the problems go beyond skepticism of federal support for scientific research (recent glimmers of hope notwithstanding).

"It's a lack of ability to think like a scientist," to ask questions that can be answered empirically, says Mr. Holt. "We have really divided our society into people who can think like scientists and those who don't."

Efforts to remedy the imbalance are taking hold. Programs help students think like scientists by teaching them to apply concepts to the kinds of problems experts tackle. The Association of American Universities is trying to improve the science teaching of freshmen and sophomores. At Bard College, students dedicate their January intersession to a "Citizen Science" course focused on complex, open-ended problems in infectious disease. Students at Arizona State University can take a hybrid course, in person and online, called "Habitable Worlds," to examine fields of stars and try to determine which ones might sustain life. The course design and learning platform are being adapted by about two dozen other institutions, many of them community colleges.

Here at the University of Oregon, the Science Literacy Program reimagines how courses are conceived of, framed, and taught to nonscience majors. The project, which began in 2010, accounts for about 20 percent of the courses that students take to fulfill their general-education science requirements.

The courses are created for maximum appeal. Instead of taking, say, "Introduction to Geology," students can enroll in "People, Rocks, & Fire." Some courses play to students' interests: "Bread 101," for example, and the "Science of Sex." Even those derived from a professor's research sound lively, like the "Physics of Life."

If branding draws students in, how the courses are structured and taught is supposed to get the material to stick. Teaching is the focus of frequent workshops for the instructors, tenured professors, and graduate students in the program. In one recent session, they analyzed their own assignments and tests for the lower- and higher-order thinking skills they expected from students. They traded tips like, Write exam questions after each class to better align teaching with assessment.

Several courses in the program use similar student-centered approaches. Students make predictions, answer questions with clickers, engage in small-group work, and, in "flipped" classrooms, interact with professors and a bevy of teaching assistants who roam around ready to clear up misconceptions.

Tone matters, too. On the first day of his class, Mr. Fisher tells students he's not out to recruit majors; he wants them simply to have a positive experience with science. "You can just see them physically relax," he says.

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In his course on the solar system, Scott Fisher, of the U. of Oregon, tries to makes astronomy approachable.

One Thursday in October, as students settled into their seats for his course "The Solar System," he caught their eyes and waved exaggeratedly. During his lesson, the wiry, caffeinated astronomer pointed to a clock at the back of the lecture hall and asked when a beam of light leaving Andromeda would be visible from Earth. "No Googling!" he shouted, circulating through the roomful of 200 students. Later, explaining human beings' capacity to see the universe in its spatial and temporal entirety, he slipped in a reference to Taylor Swift. "We are never, ever, ever going to see the whole thing," he said, echoing the singer's lyrics. In course evaluations, students describe astronomy made approachable, even fun. Many note Mr. Fisher's "passion" for the subject. A few describe the course as the best they've ever taken.

While not every instructor has what Mr. Fisher calls "a double dose of schmooze," the science-literacy courses all seek to draw in students and tame the fear that often prevents them from engaging much with science after they leave the campus.

That lack of connection carries long-term consequences, because the scientific enterprise depends on a populace that's willing to support it, says David J. Asai, senior director of science-education programs at the Howard Hughes Medical Institute, which supports Oregon's efforts. "If we as a community don't do a better job of helping our students understand the process of science," he says, "we're not doing a good job of preparing voters, teachers, and parents."

But what level of scientific literacy is adequate or desirable? And how can courses best cultivate it? Should students be able to recite Newton's third law or know how to think like a scientist? Maybe it's enough if they go on to grapple with contemporary questions like the effect of genetically modified organisms.

"Our goal is, five years hence, they've graduated and can pick up *The New York Times* science section and find it interesting and not intimidating," says Judith S. Eisen, a neurobiologist who is director of Oregon's Science Literacy Program. And if they want to learn more, they know how to find reliable sources of information. "That," she says, "would be a fantastic outcome."

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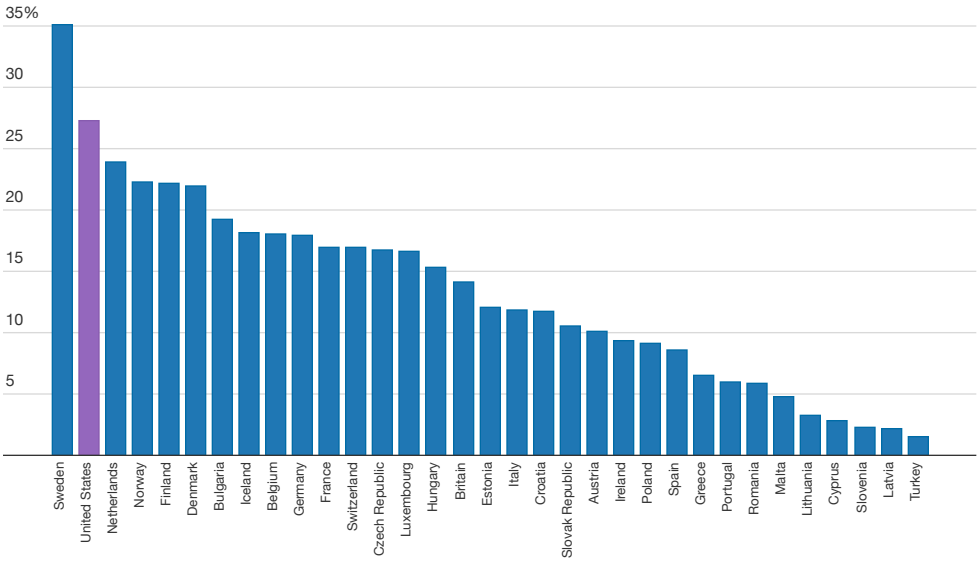
Jon D. Miller, director of the International Center for the Advancement of Scientific Literacy, at the University of Michigan at Ann Arbor, cites the same standard. Since 1988 he has tested Americans' scientific literacy, gauging their knowledge of foundational material like atoms, DNA, and probability. "If you get these simple concepts down right," he says, "it opens the door to anything."

His research, supported by the National Science Foundation, is sobering. Less than a third of adults score at least 70 out of 100 on his test, which asks if the Earth revolves around the sun or vice versa, and in what period of time. The good news is that the United States fares comparatively well, ranking second, behind Sweden, among 33 countries. General-education requirements help, but there's room for improvement, Mr. Miller says. "You don't need more courses. You just need to teach them more thoughtfully."

Science Knowledge: U.S. vs. the World

Citizens of the United States scored second-highest on a battery of tests of scientific literacy that were administered in 33 countries between 2005 and 2007. By this measure, however, less than a third of Americans are familiar with basic scientific facts.

Percent of adults who are science literate, by country



Source: Jon D. Miller, International Center for the Advancement of Scientific Literacy Get the data

That means taking into account profound changes in the relationship between people and information in the Internet age. "We've moved from a warehouse model," he says, in which people must store crates of information in their heads, to "a just-in-time world," where people can wait until they need to know something before trying to learn it.

Many disciplines are contending with that shift. In science, some scholars have homed in on ways of thinking. Edward B. Nuhfer, a retired professor of geology who has led faculty-training efforts at Idaho State University and in the California State University system, tests whether students can identify a hypothesis, understand peer review, and define a scientific theory. Courses like Bard's "Citizen Science" take that approach. Students learn how to apply computer models, what scientific tools and analytical methods to use, which questions to ask, and how to study data.

Still, balancing scientific content with ways of thinking — and accessibility with high expectations — is a challenge. At Oregon, one of Mr. Fisher's course evaluations reflects as much.

"I agree with his ideas about science literacy being important for people who are not exactly interested in the sciences," the student says. But the course apparently didn't offer enough substance: "I am walking away," the student says, "with very little information I did not have before or could not have found online within two Google searches."

Teaching students to think scientifically does not guarantee that they will. That can be especially true with topics like climate change, evolution, and the Big Bang theory that divide cultural and ideological groups, as Dan M. Kahan, a law

professor at Yale University, points out. In those cases, people's understanding of science is mediated by "cultural cognition," he argues. Their sense of identity can get in the way of a willingness to absorb information.

Mr. Kahan's research shows, for example, that people who identify themselves as very religious are far less likely than those who identify as nonreligious to answer, correctly, that human beings developed from earlier species. But when the question is tweaked to ask if that statement is true "according to the theory of evolution," the two groups answer similarly. They have comparable knowledge, but only some choose to believe it. That holds for other topics, too.

Highly educated people also have their blind spots. They use their knowledge not necessarily to help them reach a more informed conclusion, Mr. Kahan has found, but to support their previously established views. They "spring open a confabulatory escape hatch," he has written, to dodge logic.

Frustrated by sloppy thinking, scientists often resort to raising their voices of authority. But to come across as accessible, some faculty members try to play down the omniscient tone.

In the "Habitable Worlds" course at Arizona State, Ariel D. Anbar takes a playful approach, using gamification and avoiding clear-cut answers. "We rub students' noses in the fact that science is about the unknown rather than the known," says Mr. Anbar, a biogeochemist who directs the university's Center for Education Through Exploration. Too often, science professors teach a set of facts from a position of unquestioned authority, he says. "We end up teaching exactly what science isn't."

Several instructors at Oregon say they work hard not to bias their students, instead presenting evidence for them to reach their own conclusions. In a progressive haven like Eugene, climate change, evolution, and the age of the universe tend not to be lightning rods. But vaccination is. Oregon is among the states with the highest rates of opting out of shots.

The university recently had to make the case for vaccination when the campus was hit with six cases of meningitis. One student died. To contain the outbreak, health officials recommended that the university vaccinate all undergraduates.

The question of whether students would get the shot became a natural subject of discussion in the course "Science, Policy, and Biology," which typically explores how vaccines work and the debunked hypothesis that the shots have led to an increase in diagnoses of autism. Students in the class quickly concluded that concerns about vaccines were not based in science but socially constructed, says Eleanor V.H. Vandegrift, a senior instructor of biology and associate director of the Science Literacy Program.

When she asked students if they'd been vaccinated for meningitis, though, only about a third raised their hands. Some thought the vaccine they'd received before enrolling was still good (it wasn't). Others feared how much their arms would hurt or worried about being tired during finals.

Ms. Vandegrift dispensed with the program's pedagogical evenhandedness and became prescriptive. "It was the only time I shared my opinion," she says, telling students that vaccination wasn't for just their own health but also the health of those around them. "I'm not sure how much of it translated from this hypothetical to their own world," she says.

Fewer than half of Oregon's 22,000 undergraduates have been vaccinated. That might be because of a fundamental misunderstanding of probability or the youthful illusion of invincibility, says Andre Le Duc, executive director of the university's emergency-management team.

Rates of vaccination have been highest in residence halls and in Greek housing, where social pressure may have worked in the service of public health. Another persuasive force emerged around spring break, when more male students in particular got shots after going home. "My guess," says Mr. Le Duc, "is we're looking at a Mom coefficient."

Ms. Vandegrift recalls that many students in her biology course would rely on gut instinct when encountering topics like stem cells and cloning. Once they began to think through the complexities and implications, she saw their views become less fixed. Their ideology didn't always shift, she says, but they grew more receptive to new information.

That, too, is winning.

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