FACULTY

Introductory Science Moves Beyond 'Rocks for Jocks'

By JEFFREY BRAINARD | MAY 30, 2008 ✔ PREMIUM

Courses for nonmajors get increased attention

Four hundred years have passed since Galileo helped prove that the Earth orbits the Sun once a year. But today more than one-third of adult Americans do not know this basic science concept.

In a survey last year, four-fifths of respondents couldn't correctly define "molecule." And only three-fifths agreed with the statement, "Astrology is not at all scientific."

That is not good news for educators who worry that Americans are ill prepared to compete with other nations and understand political choices involving science.

But behind those disturbing numbers lie another, more encouraging, set of poll results intimately tied to the college curriculum. Americans' overall score in science literacy ranks second in the world among developed nations, behind only Sweden. That is in large part because of this country's unusual system of requiring many nonscience majors to take at least some science courses, says Jon D. Miller, a political scientist at Michigan State University who has led the survey for more than 20 years.

Mr. Miller also found that college course work in science was the factor most strongly predictive of a passing score on the survey, ahead of others like reading science magazines.

In other words, courses for nonmajors — sometimes derided by professors and students as "Rocks for Jocks" and "Physics for Poets" and as presenting watered-down fluff — may deserve more respect.

All of these polls figure in a lively debate on the best way to teach science to nonscience students. Some professors argue that these courses should emphasize analytic skills and the thinking and reasoning behind scientific concepts.

But critics charge that that is not good enough. James S. Trefil, a professor of physics at George Mason University, says that taking one or two courses from a hodgepodge of disciplines means that too many undergraduates leave college with a fragmented grasp of science. Far better, he says, to show them the big picture, which he tries to do in a course called "Great Ideas in Science."

Improvements in Literacy

Mr. Trefil has spent about three decades teaching nonmajor science courses and has become an outspoken critic of how they are usually taught. Among his "heresies," he says with a twinkle, is that laboratory sessions for these students are a waste of time. He thinks the exercises are too predictable and removed from cutting-edge science.

Mr. Trefil agrees, though, that there's heartening news in Mr. Miller's survey results. The survey found that the percentage of Americans considered scientifically literate rose from 10 percent in 1988 to 25 percent in 2007. A passing score (defined as 70 on a scale of 100 points) roughly equates to an ability to comprehend the weekly science section of The New York Times or the documentaries on the public-television show Nova, Mr. Miller says.

Another cause for optimism is that problems like global climate change and the need for renewable energy have made it easier for instructors to interest nonmajors in science courses and package them as relevant and even (gasp) fun, educators report. The reputation of science as boring and only for nerds is beginning to change.

This can be seen at the University of California at Berkeley, where the physicist Richard A. Muller started a course in 2000 called "Physics for Future Presidents." Students this year voted the class the best on the campus, and videos of Mr. Muller's lectures are the most popular Berkeley offerings on YouTube.

All Over the Map

Nevertheless, these courses vary greatly in focus and breadth, a potential obstacle to producing graduates with a shared base of basic knowledge.

Forty states require their public universities to offer one year of general education, which typically includes two semesters in science. However, a growing number of undergraduates place out of those courses using Advanced Placement credits earned in high school, says Carol Geary Schneider, president of the Association of American Colleges and Universities. Unfortunately, she says, their high-school courses often can't compare in rigor.

Ms. Schneider's group and the American Association for the Advancement of Science have also said that the college courses for nonscience majors could benefit from more consistency and coherence.

Competing ideas exist about how best to do that, and Mr. Trefil holds a minority view: Nonmajors should take at least one survey course that describes the big, fundamental concepts of all the major disciplines of the natural sciences. He has described roughly 20 in all, like the conservation of energy, the atomic structure of matter, and the predictability of the universe.

In 1990 he and Robert M. Hazen, an earth scientist at George Mason, created the "Great Ideas" course, which they continue to teach today. Both men have plenty of practice presenting science to nonspecialists. Between them they have written 40 popular books on science, and Mr. Trefil has regularly contributed to Smithsonian and Astronomy magazines.

More than 200 other institutions use the textbook they wrote for the course, Mr. Trefil says.

He also contributed scientific content to a well-known, even notorious, book about what all educated people should know: E.D. Hirsch Jr.'s Cultural Literacy (Houghton-Mifflin), published in 1987. Although the book's idea of a canon of intellectual thought remains controversial, Mr. Trefil argues that scientists are more in agreement than humanities scholars are about essential big ideas.

"If you want to know about the universe, and you don't know the first law of thermodynamics, then you can't say you know much about the universe," he says. (Pop-quiz answer: That law says that all energy is conserved, not permanently lost or gained.)

A 'Heretic' Teaches His Way

Mr. Trefil's approach does require a headlong sprint, as he shows while teaching the course at George Mason on a recent April evening.

Fifty students file in for his weekly, three-hour lecture. Many are part-time commuters juggling study and work. The entire course lasts only 15 evenings, so he launches in.

He opens with genetic engineering, weaving in some pop culture — "Let me get back to CSI," he says — by explaining how the now-mature technology of DNA fingerprinting helps cops catch criminals.

But he doesn't miss an opportunity to mention a related mystery at the cutting edge of scientific research: Why do large stretches of chromosomes consist of repeating sequences called "junk" DNA that don't contain genes, and what is their function? (They may represent remnants of evolution, he says, "like treasures in your attic that you can't get rid of.")

From there, it's a hop to genetically modified crops, engineered to excrete an insecticide; a skip through human cloning; and a jump to stem cells and "regenerative medicine." Yes, scientists may one day grow replacements for diseased organs, Mr. Trefil says, but think how society would be turned upside down if no one ever died.

An assistant professor would have to wait 500 years for tenure, he jokes. (The students, still new to college culture, don't seem to get it.)

Afterward, some students praise the course for drawing them into an area they had viewed at first with dread.

"I'm having a blast," says Hattie Barker, an artist who is working to complete her bachelor's degree after starting and stopping college three decades ago.

Mr. Trefil's course "is really difficult for me," she says. But it's also helped her to understand and appreciate news-media reports on science — like a Smithsonian article she read for fun that described a black hole as "gathering starlight."

"I thought it was just such a beautiful image," she says. "I find myself thinking about things I would have glossed over before."

Not everyone is enraptured, however. One student thumbs through a fashion magazine. Another sleeps, head down on his desk.

A Different Emphasis

Faculty members, too, can be indifferent to his course, Mr. Trefil says. That is particularly true at research universities, where more than a quarter of undergraduates are enrolled.

He thinks that is because a survey course like his is harder to prepare and teach than one that stays safely within the comfort zone of a single discipline. The subspecialization typical of academic scientists means that some are often surprisingly unfamiliar with foundational ideas outside their own fields. And research institutions hire and promote faculty members based more on scholarly productivity than good teaching.

Michigan State University appears to be one of the few research universities working to break that and systematically improve its science courses for nonmajors. But it is following a path different from Mr. Trefil's.

A faculty committee last year developed a set of eight "learning objectives" in scientific and quantitative reasoning for all students, including nonmajors. The goals emphasize the scientific method, how researchers form hypotheses and collect and evaluate data to test them.

Other faculty members from disciplines throughout the university were asked to rank the goals in importance, and 200 replied. The top-rated objective included preparing students "to distinguish science from pseudoscience and nonscience." Another involved social and ethical issues.

A notable aspect of the effort is a plan to measure students' educational gains by testing their grasp of those concepts as entering freshmen and again as sophomores. That's in line with the calls from outside academe for greater accountability by universities for what their students learn. Such assessments are rare. Michigan State adapted its test from one used by James Madison University.

"If we can do this at Michigan State University, with 45,000 students and a very typical research, land-grant university," says Diane Ebert-May, a professor of plant biology who helped develop the objectives, "then no one else has an excuse, because we're big and we're unwieldy, we serve every kind of kid."

Michigan State's learning objectives don't spell out content, but the nonmajor science courses there often cover a broader swath of science than might be suggested by their titles or by Mr. Trefil's critique, says Ms. Ebert-May, who has won grants from the National Science Foundation to study science education. In her nonmajors course on environmental science, she uses the topic of infectious diseases to teach about cell biology and global climate change. (A warming globe will tend to hasten the spread of tropical diseases.)

Ms. Ebert-May says she worries that a course on big ideas in science "will become the litany of big ideas, not the thinking and reasoning about the science from which those big ideas were derived."

Those analytical skills will help nonmajors remain scientifically literate over their lifetimes as science evolves, she says.

Tools for Citizenship

The relative importance of scientific findings versus what the educational philosopher John Dewey called "scientific habits of mind" is an old but a still active debate in higher education. Harvard University's faculty members struggled with it when they reworked the freshman curriculum last year.

Mr. Trefil says the emphasis on analytical skills as articulated at Michigan State and other universities is actually a disservice to students.

First, he disputes that an analytical focus helps students to educate themselves about fundamental concepts in science not covered in their college courses. Second, that emphasis suggests that the faculty members don't understand that science courses for nonmajors should be designed to educate citizens, not produce more research scientists trained like themselves.

Mr. Trefil worries especially about statements like that in one of Michigan State's learning objectives, that students be able to "evaluate the credibility" of scientific information useful in public-policy debates. Anyone but a practicing climate scientist would probably find it impossible to do that about, say, the computer models that are the basis of the finding that global warming is caused substantially by humans, he says.

"The amount and type of scientific knowledge needed to function as a citizen is limited," he says, but he thinks of that knowledge "as a kind of entry pass into the civic arena." Without that minimal knowledge, he says, "No one can make reasonable choices about these issues."

TRUE OR FALSE: WE KNOW SCIENCE

Many Americans don't know the basics of modern science. Here are questions asked last year on a long-running survey of adults conducted by Michigan State University. Below are answers and the percentage of respondents who answered correctly.

True or false:

1. The earliest humans lived at the same time as the dinosaurs.

2. The continents on which we live have been moving their location for millions of years and will continue to move in the future.

3. Ordinary tomatoes, the ones we normally eat, do not have genes, whereas genetically modified tomatoes do.

4. Antibiotics kill viruses as well as bacteria.

5. Electrons are smaller than atoms.

6. Lasers work by focusing sound waves.

7. The universe began with a huge explosion.

8. Light travels faster than sound.

9. The center of the earth is very hot.

10. The Earth goes around the Sun once each year.

11. Astrology is not at all scientific.

12. Human beings, as we know them today, developed from earlier species of animals.

13. All plants and animals have DNA.

14. More than half of human genes are identical to those of mice.

15. Humans have somewhat less than half of their DNA in common with chimpanzees.

Correct answers (and percent of people who knew them): 1. False (50%); 2. True (71%); 3. False (49%); 4. False (55%); 5. True (48%); 6. False (46%); 7. True (30%); 8. True (82%); 9. True (80%); 10. True (63%); 11. True (60%); 12. True (40%); 13. True (77%); 14. True (34%); 15. False (40%)

Provide a definition of:

16. What it means to study something scientifically.

17. Experiment.

18. The meaning of the probability of one in four.

19. Molecule.

20. DNA.

21. Stem cell.

Percent of people who gave an answer considered correct: 16. (29%); 17. (50%); 18. (73%); 19. (18%); 20. (34%); 21. (15%)

RESOURCES FOR TEACHING SCIENCE TO NONMAJORS

- The Sciences: An Integrative Approach, by Robert M. Hazen and James Trefil (Wiley, 2006). This textbook is for a survey course for nonmajors spanning the natural sciences.
- Why Science? by James Trefil (Teachers College Press, 2008). This is a book-length essay that argues for the survey course as opposed to other methods for teaching nonmajors.

- Chemistry in Context: Applying Chemistry to Society, by the American Chemical Society (McGraw-Hill, 2008). This textbook teaches chemistry through contemporary technological issues like global warming, alternate fuels, nutrition, and genetic engineering.
- Science as a Way of Knowing: The Foundations of Modern Biology, by John A. Moore (Harvard University Press, 1999). The book offers a history of biology that also explores geology and the scientific method.
- Frontiers of Science (http://www.sciencecore.columbia.edu). The site holds lecture videos and other material for a team-taught, interdisciplinary science course required in Columbia University's core curriculum for undergraduates.
- Physics for Future Presidents (http://muller.lbl.gov/teaching/Physics10/PffP.html). The site holds material for a course for nonmajors at the University of California at Berkeley taught by Richard A. Muller, who wrote a book and a textbook with the same name. The site includes links to podcasts of his lectures.
- Science Education for New Civic Engagements and Responsibilities (http://www.sencer.net). This multiuniversity project is designed to improve courses in science, mathematics, and engineering for nonmajors and majors by emphasizing topics of practical interest for citizens.
- "Engaging Science, Advancing Learning: General Education, Majors, and the New Global Century," (http://www.aacu.org/meetings/engaging_science/index.cfm). This conference, sponsored by the Association of American Colleges and Universities, will be held in November in Providence, R.I.

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