SCIENCE LITERACY AT THE COLLEGE LEVEL

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PHYSICS TODAY has covered many innovative approaches to teaching science. My comments here deal with designing science literacy courses at the college level. My own interest in science literacy stems from my efforts to teach adults whose interest in science, apparently stamped out in secondary school, had been renewed once they had matured. As do some other schools, Rice University has a special course for nonscientists to satisfy basic science requirements. As the director of this four-year-old effort, I can identify a number of problems that I feel should be addressed when designing such courses.

First let's consider how well science is taught to *science* majors. To a large extent, these students are apprentices, and so they will tolerate quite mediocre texts and teaching, viewing these as necessary prerequisites for entering the guild. Many texts appear to have been written more to impress colleagues than to educate students. In any event, if science students don't understand something, they tend to blame themselves.

By comparison, nonmajors are neither science apprentices nor are they, as is often presumed, blank slates. Instead they emerge from high school with a wide variety of attitudes toward science education, including outright hostility. If they don't understand something, they often blame the instructor. The problem with simply mandating that all students take a minimum number of introductory science and math courses is that some otherwise able students are too poorly grounded to complete them satisfactorily. A student may go on to be a famous author after flunking out of college owing to Math 100—not the ideal alumni profile. At Rice about 250 nonscience students each year take our two-semester introductory course, Natural Science 101/102, out of a total undergraduate enrollment of about 2500.

Who will teach such courses? Available science faculty is limited. Innovative, hands-on, one-on-one classes of 15 to 20 students are not easily staffed, although approaches to teaching science literacy courses typically assume a small student–teacher ratio. In addition, the proposal-driven funding of academic research has largely set teaching priorities: First come specialized graduate courses; second are standard graduate courses; third, undergraduate courses in the major; and a distant fourth, anything else (including science courses for nonscientists). Teaching is a zero-sum game; a faculty member who teaches nonmajors (even if a noble cause!) cannot then teach as many courses for majors and graduate students. In our course, we now have two professors who take turns giving blocks of lectures to two large classes, followed up by smaller recitation sections led by other instructors or postdocs.

Our class has a mix of humanities, sociology, music and architecture majors. No single group seems an acute problem, but the disparity in preparation is. Any basic science course must repeat some material that the students have already seen in high school. Unfortunately, while science and engineering students take review material in stride, nonscientists often object viscerally to being faced anew with material that they supposedly covered in high school. They feel they have "had" this material, and having "finished it," they don't ever want to be challenged on it again. This attitude arguably presents the severest problem, and it tends to show up on student evaluations of the course. To quote from one such evaluation: "The professors are trying to make us think like scientists"—which the student offered as harsh criticism! (From the professor's point of view, it is one thing to understand that you are going to get mixed reviews, but another to knock yourself out for such reviews.)

An approach we have pursued is to abandon the ubiquitous historically based syllabus and use one that expands on the physics of harmonic oscillators. On the first day we show how a metal rod can be made to ring with various pure tones; from this demonstration we develop concepts such as nodes and oscillatory motion. An oscillating rod is effectively a two-slit experiment, where the sound waves from the coherently moving tips create an interference pattern across the classroom. We then go on to discuss these sound waves and interference patterns; we also note that the slopes of these oscillatory curves are oscillatory as well. In this way we work into elementary differentiation. The exponential function arises naturally as the way oscillating systems run down (as well as how populations explode). Diffraction gratings are introduced as generalizations of the two-slit experiment, and spectral lines of mercury introduce a puzzle parallel to the rod—namely, do atoms "ring," and if so, why all at the same frequencies? Bragg scattering and some elementary quantum phenomena then follow.

In the second term we branch out into topics such as nuclear physics ("systematics" would be more accurate), giving the students just enough to understand why reactors produce radioactivity and to answer questions such as: Does radioactivity itself produce more radioactivity? Were all the elements created in a blinding flash? From the natural abundances of radioactive isotopes, we show that the Earth is a few billion years old, not much more and not much less. The aim is to create a paradigm that is fresh to those students who already have some science background, yet accessible to those without. An important component of the course is that we give weekly tests in the recitation sections on all aspects covered that week. This testing has been very effective at maintaining

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attention and attendance, and it provides feedback on what is and is not getting across.

Good textbooks are difficult for research professors to locate. They are not in the obvious places. Most university libraries do not archive textbooks, and the shelf life of existing ones is short. Moreover, many texts that are ostensibly intended for nonscientists simply omit mathematics on the presumption that it is the mathematics that poses difficulties. What then remains is often little but a litany of declarative knowledge to be memorized until the next test and then forgotten—a technique usually perfected in high school. Likewise, many students seem to have been trained to solve problem sets by substituting uncritically into stock formulas, with only a minimal idea of what the formulas represent. This rote is what they then expect in the way of homework. One must therefore be clear about the intention of the homework and the intended level of difficulty rather than assuming the students will understand what one is trying to do. Otherwise, even a pitifully obvious extension of class or reading material will frequently be viewed as "incredibly difficult" or "unrelated to the lecture."

As Arnold Arons accurately points out in his book *A Guide to Introductory Physics Teaching* (Wiley, New York, 1990), one can create courses that are fun but that the students get essentially nothing out of. As soon as you get into anything requiring quantitative reasoning, students believe, the fun is out the door. At Rice the attitude problem is exacerbated because the students regard the course as "required"; the alternative is four semesters of standard introductory science (versus just two for this course). In addition, 40% of our students take the course after their freshman year, and 50% take it pass/fail. All of these factors increase the proportion of students who don't really want to take the course, who see no immediate value in the course, or who hope to pass with minimal commitment. Nevertheless, in evaluating the course, roughly half are at least grudgingly satisfied. One student even changed his major to engineering.

Based on my experience, I am convinced that it is possible to construct a large course that imparts science literacy and can be taught by rank and file science faculty. For many colleges and universities, this may be the most practical approach. The need for such courses is not likely to go away soon. ■