The Surprising Effectiveness of College Scientific Literacy Courses

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Research by Jon Miller, professor of Interdisciplinary Studies and director of the International Center for Scientific Literacy at Michigan State University, shows that the U.S. scientific literacy course requirements for nonscience college students pull the United States into second place in international rankings of adult scientific literacy. This despite the poor science scores of U.S. primary and secondary school students as compared with other nations. The far lower adult scientific literacy rankings of most European nations and other industrialized nations appear to be due to the lack of any such college scientific literacy requirement in those nations. Instituting such a requirement in all nations, and improving the quality and quantity of such courses on U.S. campuses, would increase global scientific literacy significantly, arguably doubling Europe's scientific literacy rate. In view of this result and today's crying need for scientific literacy, physics educators should make physics for nonscientists their top priority.

The Importance of Scientific Literacy

Industrialized democracies cannot survive unless their citizens are scientifically literate. The life's blood of industrial nations is intertwined with science and technology. If an industrialized nation is democratic, its citizens must ultimately make the crucial choices about the uses of science and technology. A scientifically illiterate citizenry is thus a prescription for disaster. Indeed, recent history illustrates vividly that the entire world must turn from violence, from fear of knowledge, from irrational and extreme ideologies, toward peaceful co-existence, science, and reason. Surely scientific literacy, including especially critical thinking and an understanding of the processes of science, are crucial to this transition.

While the power of science and technology threatens disaster if we remain scientifically illiterate, if used wisely it also offers great benefit: *If used wisely*, it can provide a comfortable life for all people, a life without poverty, hunger, or uncared-for disease, a life to which only the very rich could aspire in times past. But to use this power wisely, we must pay a price: We must provide at least a minimal science and technology education to all people. This does not seem an exorbitant price for such a sweet reward, especially since good science education practices are so much fun to provide and to receive, but we are not paying this price.

We physicists and physics educators in particular are not paying this price. The physics profession pays scant attention to scientific literacy except, ironically, to scold the general citizenry for their physics illiteracy. Scientific literacy has the lowest possible priority in most college physics departments, if indeed it is taught at all.[1,2]

The remainder of this essay will point out a simple and practical strategy that can move us surprisingly far toward the goal of general scientific literacy.

Measuring Scientific Literacy

What is scientific literacy? Jon Miller is perhaps the leading world expert on the international study and

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measurement of scientific literacy.[3] But according to the "Web of Science" citation index, Miller's scientific literacy work is cited by physicists only twice, in *Physics Today* in 1984 and 1990. Thus, most physics educators don't know his research, but they should.

In a paper presented at the 2007 annual meeting of the AAAS,[4] Miller defines scientific literacy as "the level of understanding of science and technology needed to function in a modern industrial society. This … does not imply an ideal level of understanding, but rather a minimal threshold level."

Through testing, Miller has found evidence for two essential dimensions of scientific literacy. The first is a basic knowledge of key scientific concepts such as stem cell, molecule, nanometer, neuron, laser, DNA, nuclear power, continental drift, the cause of the seasons, biological evolution, and the greenhouse effect. The second dimension is an understanding of the process of science—an understanding that science bases its conclusions on evidence and reason rather than emotion, ideology, ancient texts, authority figures, superstition, or religion. Scientifically literate people should thus understand what it means to study something scientifically, be able to define words like "experiment" or "hypothesis," and understand that astrology is not at all scientific.

Miller and his colleagues have developed a core set of knowledge and process questions used in studies of adults in all 27 European Union nations plus the United States, Canada, China, Japan, Korea, India, and New Zealand. These questions, continually enriched to reflect new scientific and technological growth, have been used in adult scientific literacy tests since 1988 to obtain a consistent reading of scientific literacy during two decades. A score of 70 on these tests represents sufficient knowledge to understand science and technology stories in the daily newspapers, while a person scoring below the middle 60s would have a difficult time making sense of current debates over such issues as global warming or embryonic stem cells. Thus, people scoring 70 or more are considered "scientifically literate."

One conclusion from Miller's work is that global scientific literacy is shockingly low. Among the 34 nations tested in 2005, the scientifically literate fraction—the "scientific literacy rate"—of the adult population rose above 30% in only one nation (Sweden, 35%). The United States was second with a scientific literacy rate of 28%—a surprisingly positive result that I will discuss further below. Netherlands, Norway, Finland, and Denmark were between 20 and 25%. In 15 European nations, including Germany, France, and the United Kingdom, the scientific literacy rate was between 10 and 19%. In 13 other nations, including Ireland, Japan, and Turkey, the rate was less than 10%. Large developing nations such as China, India, Mexico, and Brazil were not tested in 2005.

However, adult scientific literacy has been rising in most nations. For example, the U.S. scientific literacy rate rose steadily from 10% in 1988 to 28% in 2005.

In all of Miller's results since he began testing in 1988, the United States has scored above nearly all other nations. This is surprising. After all, international tests of primary and secondary students show consistently and convincingly that American students perform poorly in science, as compared with other nations. What happens between secondary school and adulthood to bring American adults up to the top international ranks in studies of adult scientific literacy?

Miller notes that the United States is the only major nation to require all 4-year college students to complete at least two half-year science courses. Thus, even nonscience college students must study at least a little science. Most U.S. colleges offer "liberal-arts" science courses specifically for these students, courses designed for general science knowledge rather than for technical expertise.

To investigate why Americans score so highly, Miller obtained the following information, which he suspected might be correlated with scientific literacy, from each U.S. examinee in the 2005 tests: age, gender, highest level of education, number of college science courses, number of children present in the household, informal science learning (museums, magazines, etc.), science-related resources, and personal religious beliefs. He then applied a standard statistical method known as "path analysis" to determine the influence of each of these variables on the scores of U.S. adults in the 2005 tests.

The results were striking. The strongest predictor of adult scientific literacy was the number of college science courses taken. The "total effect" of this variable on scientific literacy was 75%, meaning roughly that 75% of the variability in different people's scientific literacy scores could be predicted simply from the number of college science courses they had taken. In testing for this effect, the number of college science courses was grouped into just three levels: (1) no courses, (2) one to three one-semester courses, and (3) four or more courses (these individuals were mostly science and engineering students). Those individuals falling into categories (2) and (3) were far more likely (with a total effect of 75%) to be tested as "scientifically literate" than those who fell into category (1).

Improving Scientific Literacy

Thus, even though only about 25% of all Americans graduate from college, the U.S. requirement that nonscience college students take at least two semesters of science makes a major contribution to the adult scientific literacy of U.S. nonscientists. Nearly all other nations follow the European university system, which does not require students to enroll in courses outside their chosen professional field. It is striking that, despite the poor science scores of U.S. primary and secondary school students as compared with other nations, the effect of the U.S. college science requirement is strong enough to pull the United States into the top international ranks of adult scientific literacy.

It seems likely that all nations can significantly increase their adult scientific literacy by requiring nonscience college students to take two or three science literacy courses. How large might this increase be? Since European secondary school students score above the United States on international science tests, we might expect that European adults would score above U.S. adults on scientific literacy tests if European college students were also required to take two or three science courses. Under this assumption, the median European scientific literacy rate of 14% in Miller's 2005 tests could be expected to rise to at least the 28% U.S. rate. Thus, such a requirement should at least double Europe's scientific literacy rate!

Europe and all other nations should require all college students to take at least two or three science courses designed for general scientific literacy. Evidence shows that this will significantly increase the fraction of citizens who are scientifically literate. In light of the anti-science, pseudoscience, superstition, and religious fanaticism that are so tragically at work everywhere in the world today, physicists and all other scientists must place scientific literacy and this conclusion at the top of their list of priorities.

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References

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3. For a general overview of Miller's research, see James Trefil, *Why Science* (Teacher's College Press, New York, 2008), Chap. 6.
4. Jon D. Miller, "The impact of college science courses for non-science majors on adult science literacy," a paper presented to a symposium titled "The Critical Role of College Science Courses for Non-Majors" at the annual meeting of the AAAS, 18 Feb. 2007, San Francisco.

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