Policy Forum

Are Our Universities Rotten at the "Core"?

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In May 1978, the Harvard faculty voted, by a margin of greater than 3 to 1, to institute a "Core Curriculum"—a "core" of knowledge that all students in the college should have before they can graduate and join "the society of educated men and women" (*1*). It is the thesis of this policy forum that the core curriculum minimizes science and that the vast majority of students who graduate from Harvard are, in a real sense, uneducated because they know almost no science. This conclusion would be both uninteresting and trivial if it were not also true of the graduates of many, and perhaps most, other U.S. colleges and universities. An essential concept in analyzing the problem is that learning in science is primarily vertical, or intensive, whereas that in the humanities is primarily horizontal, or extensive.

The Two Cultures

The education in science available at Harvard and at many other American universities is superb. But very little of it is required of those who do not elect to concentrate in the sciences. We are educating our students to fit into C. P. Snow's two cultures: one group in the humanities and an entirely different group in science and technology. But this division is lopsided; in the better colleges, at least, students in science find out something about the modern technological world and in addition learn a modest amount about the humanities and social sciences. The humanists cannot make a reciprocal claim, nor can many of the social scientists. The problem is compounded because we pretend that we really are providing a liberal education for all of our students; we pretend that our graduates have a common core of knowledge that embraces both cultures.

Requirements

Many of the most prestigious American colleges and universities require the equivalent of only about two half-courses in science for graduation, and some of these courses are special, watered-down courses at that. The list of those with minimal requirements (*2*) includes the University of California, Columbia University, Harvard University, Haverford College, the University of Michigan, Northwestern University, Oberlin College, the University of Wisconsin, and many others; the University of Chicago demands two full courses, and the Massachusetts Institute of Technology (MIT) and the California Institute of Technology (CalTech) require much science plus about 20 percent of each student's curriculum in humanities and social science courses. Columbia explains its philosophy as follows (*3*):

> The science requirement at Columbia is intended to provide students the opportunity to learn what scientists do, how they think, what kinds of questions they consider, what procedures they develop to evaluate the results of their research, and in what forms they present their knowledge.

Note that Columbia speaks about how scientists think, but not about science. There is no word about atomic energy or metallurgy or medicine or agriculture or chemical synthesis or genetics or immunology or infinite series or any real subject in science or mathematics. In contrast to its modern requirements, Harvard's curriculum in 1849–1850 included (*4*) a course in science or mathematics, or both, in every semester of every year.

In 1987, when the contributions of science to society, for good and for evil, have been expanded, almost beyond recognition compared to those in 1850, Harvard has reduced its requirements in science to two half-courses. Most other colleges and universities, other than institutes of technology and engineering schools, have similar requirements.

Advances in Science

Perhaps it serves a purpose to recite some of the intellectual advances in science that have occurred in the last half-century, long after Copernicus and Galileo and Newton and Lavoisier and Darwin and Pasteur and Kekulé had made their contributions to the intellectual heritage of mankind. In particular, the critical discovery of atomic fission (*5*) was not published until 1939; in 1937, no one knew how the sun produced its light and heat. Neither the destruction caused by atomic weapons nor the potential and hazards of atomic power had been recognized.

But the advances in science in the last half-century have scarcely been confined to nuclear physics. The first practical digital computer was invented during World War II. The discoveries in solid-state physics have revolutionized computers, as well as phonographs, TV sets, cameras, and much else.

We are the fortunate generation, living after the discovery of penicillin and before the oil runs out. Almost everyone has benefited in important ways from modern medicine; and a good many individuals as well as society have benefited from birth control pills. The role of science and technology in discovering oil and stretching the supply is less often acknowledged, but equally real. In the practical world, lasers are used for eye surgery, for drilling holes in diamonds and sapphires that are used to form synthetic fibers, and for much else; they are touted today as possible military weapons. Astronomy has advanced the idea of black holes and is engaged with the question as to whether the universe will expand forever or collapse, or will cycle forever. Geology has been enhanced by the concept of tectonic plates, and on a practical level by the beginnings of earthquake prediction.

But the greatest intellectual revolution of the last 40 years may have taken place in biology. Can anyone be considered educated today who does not understand a little about molecular biology? Furthermore, if we are to teach molecular biology, it will be necessary also to teach some organic chemistry, and that in turn demands a background of general chemistry. This sequence in subjects, this example of the vertical structure of learning in the sciences, is typical. Primary discoveries that provided the underpinning of molecular biology began with the determination in the early 1950s of the structure of proteins and of nucleic acids. These discoveries led to the concept and then the determination of the genetic code and to a methodology for synthesizing genes. The practical consequences are beginning to be felt throughout society; for example, it is now possible to prepare a vaccine against hepatitis B that has none of the problems connected with the vaccine made from live virus (*6*). The intellectual consequences of biochemical discovery provide a basis, independent of classical taxonomy, for establishing the evolutionary sequence of living organisms, and therefore provide a solid background for combating the present

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craze of creationism—a craze that has now reached our Supreme Court (7). Modern science can provide an understanding of some disease processes at the molecular level, and it can show how to design new pharmaceuticals by rational pathways.

Should not college students learn something about some of these various scientific advances even at the price—and it is a real price—of knowing less literature and history at graduation? Which will be easier to learn without instruction in later life: more Shakespeare or molecular biology? How is it possible to consider someone as educated who knows virtually none of the wealth of new scientific principles accumulated since, and before, 1937? The graduates of our prestigious institutions are a sizable fraction of the individuals who become the legislators, the educators, the lawyers and judges, and the business executives in America. They will have to exert judgments on problems concerning the safety of nuclear energy plants, the desirable and undesirable effects of specific chemicals in our society, the dangers and advantages of genetic engineering with bacteria for both medical and agricultural purposes, the proper measures to combat acid rain, and dozens of other questions, most of which relate to opportunities and difficulties that have not yet been imagined because the relevant science has not been discovered. It will serve our students and the nation well if they know enough science to provide them with a background for future learning, and if they can at least listen intelligently to the arguments of experts; perhaps they will even be able to distinguish them from purported experts. Lack of knowledge will not prevent them from having opinions; it will only prevent them from having informed opinions.

Reasons

How was it possible that the Harvard faculty voted by an overwhelming majority to install a curriculum that all but ignores science? Why have most major universities and colleges done likewise?

Of course, the number of faculty in the humanities and social sciences at Harvard exceeds the number in the sciences. If everyone simply voted to enhance the importance of his or her own discipline—a possible and understandable, if somewhat shortsighted attitude—the core curriculum would have passed. But in fact, the science faculty at Harvard also voted for the core, and science faculties elsewhere presumably support similar programs. In conversations with faculty, it became clear why. Scientists do not really want to teach the "unwashed." The mathematicians do not even enjoy teaching experimental scientists; they want pure mathematicians in their classes. In justification of their unhappiness about teaching nonscientists, scientists frequently state that it is not possible to teach anyone who does not want to learn. That is true. But the great colleges and universities of America have a choice of students and, if they wished, could select those who are eager to learn science. Quite possibly, among the brilliant students now in our universities, we would find that many could learn science if that was what the faculty expected of them. We have here an example of self-fulfilling prophesy; we tell our students, by our requirements, that science is all but irrelevant to education, and then are surprised when they do not seem particularly enthusiastic about learning it.

Perhaps the worst aspect of programs, such as the core curriculum at Harvard or statements of purpose such as that of Columbia or similar programs and statements from other elite colleges and universities, is the signal that they send to the high schools: do not bother with science. Where, however, are the standards to come from if not from above? We are now riding a downward spiral, but if universities demanded some real science from their students, the high schools might emphasize the importance of working toward better preparation in science and mathematics. The result would not be instantaneous, but in a generation we would have much better education.

Intensive and Extensive Subjects

If one looks in college catalogs, one finds that the prerequisites for courses in science are much more prescriptive than those for the humanities. The prerequisites for physical chemistry include general chemistry and general physics and differential equations. Differential equations has elementary calculus as a prerequisite, and so does physics. To study calculus, students have a need to know algebra. The prerequisite for a course in quantum mechanics includes physical chemistry, which has all the prerequisites just listed. One finds many similar examples in the sciences in which one course is built on top of another in vertical sequences. Sometimes the prerequisite comes from a different science than the one being taught; the base for science instruction has some breadth. In contrast to this vertical or more properly pyramidal arrangement, most courses in the humanities have few prerequisites, but assume that students possess a broad knowledge of auxiliary materials. Elementary language courses and some courses in social science (particularly in economics and psychology) share with the sciences the need for prerequisites, although the structure of even these courses is not generally as vertical as those in most of science.

The distinction between intensive and extensive learning is relevant to the special courses in science repeatedly created for nonscientists. It explains why such courses are so difficult to design, and so frequently fail in their purpose. If scientists try to teach nonscientists molecular biology without chemistry, or quantum theory without mathematics, they are unlikely to succeed. Faced with minimal allowance of time and minimal effort on the part of students, scientists try to skip teaching the fundamentals, the prerequisites, that they demand of their own students. Then the courses for nonscientists, instead of being easier than those for students of science, become really impossible. Or, if they are deliberately made easy, they are almost devoid of content and do not even show "how [scientists] think." If they cover only a specialized field, they necessarily give no sense of the sweep of science, and may fail for lack of background besides.

Nevertheless, special courses in science probably are needed. We know, experimentally, that they are needed, at least at present, because they have been invented and reinvented in one university after another. The special courses in the sciences are not needed because science is too hard or because humanists have a different kind of intelligence; the special courses are needed, and are difficult to construct, because in the sciences, one idea is built on top of another, one concept (say thermodynamics) built on another (such as calculus). Because of the vertical nature of learning in science, scientists cannot teach enough in two half-courses to make sense. But if universities and liberal arts colleges would demand as many courses in science as MIT and CalTech require in the humanities, we could lead our students up a gentle slope to a considerable level of learning.

REFERENCES AND NOTES

1. P. Keller, "Getting at the core: Curricular reform at Harvard" (Harvard Univ. Press, Cambridge, MA, 1982).
2. Abstracted from college catalogs.
3. *Columbia University Bulletin* (Columbia College, New York, 1987), p. 46.
4. *A Catalogue of the Officers and Students of Harvard College for the Academical Year 1849–1850* (Metcalf, Cambridge, MA, 1849), pp. 42–47.
5. O. Hahn and F. Strassmann, *Naturwissenschaften* **27**, 89 (1939); *Phys. Z.* **40**, 673 (1939).
6. R. Ward, *Nature (London)* **324**, 506 (1986); W. J. McAleer *et al.*, *ibid.* **307**, 178 (1984).
7. Edwards *v.* Aguilland *et al.*, "Brief for amicus curiae, the National Academy of Sciences urging affirmance" (No. 85-1513, Supreme Court of the United States, October term, 1985), pp. 9–10.