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"Rocks for Jocks" Will No Longer Do

General Science in College: *The Key to Scientific Literacy*

By Robert M. Hazen and James Trefil
From *The Chronicle of Higher Education*

IT is no secret that the average college graduate is scientifically illiterate, unable to understand the simplest science-related newspaper article. Debate over what to do about this crisis has been confused by lack of a clear definition of scientific literacy. Many scientists believe the problem would be solved if more students majored in science. But that ignores the vast majority who have no intention of becoming professional scientists. Nonscientists need the background to grasp and deal with matters that involve science and technology. This ability to understand science in its day-to-day context is scientific literacy.

Most societal issues concerning science and technology require a broad range of knowledge. To understand debate over disposal of nuclear waste, for example, requires knowledge of how nuclei decay to produce radiation (physics), how radioactive atoms interact with their environment (chemistry), how radioactivity can enter the biosphere (earth science), and how it will affect living things (biology.) Other issues, such as global warming, space research, and alternative energy sources likewise depend on a spectrum of scientific concepts, although clearly more than science is involved.

The scientifically literate nonscientist needs to understand a little bit of several disciplines to cope with such issues. Scientific literacy thus is a grasp of an eclectic mix of facts, vocabulary, and principles. It is not the specialized knowledge of experts, nor does it rely on jargon and complex mathematics.

In college, most nonscience majors are required to take one or two science courses, at most. Not surprisingly, they usually select the offering with the least threatening reputation—perhaps "physics for poets" or "rocks for jocks." Such introductory courses on specific disciplines cannot produce scientifically literate graduates.

Science forms a web of knowledge about the universe, and the key to scientific literacy is general science principles rather than esoteric detail. Many ways exist to achieve this synthesis,

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but any general treatment should take advantage of the fact that virtually everything in science is based on a few simple ideas.

We have found it particularly useful to organize scientific knowledge around 19 overarching principles. The most basic principle, the starting point for all science (and any science course), is that the universe is regular, predictable, and quantifiable. (It is remarkable how many college freshmen, even science majors, have no clear idea of how science differs from religion, philosophy, and art as a way of understanding our place in the cosmos.)

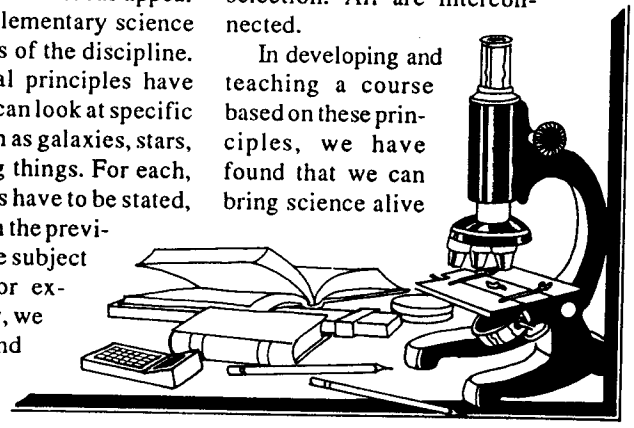
Next come principles shared by all sciences—e.g., Newton's laws of force and motion, the laws of thermodynamics governing energy and entropy, the equivalence of electricity and magnetism, and the atomic structure of matter. These are not abstract concepts. They apply to everyday life, explaining, for example, the reasons for seat belts, the physics of making a pot of soup, and the contrast between static cling and refrigerator magnets. In one form or another, all these ideas appear in virtually every elementary science textbook, regardless of the discipline.

Once the general principles have been laid down, we can look at specific natural systems such as galaxies, stars, the earth, and living things. For each, additional principles have to be stated, which, together with the previous ones, bind all the subject matter together. For example, in astronomy, we can show that stars and planets form and move in accordance with Newton's laws, that stars eventually die as dictated by the laws of thermodynamics, that nuclear reactions fuel stars by the conversion of mass into energy, and that stars produce light as a consequence of electromagnetism.

Two basic ideas—plate tectonics and earth cycles (rock, water, and atmosphere)—unify the earth sciences. The laws of thermodynamics decree that no feature on the earth's surface is permanent. This principle can explain geologic time, gradualism, and the causes of earthquakes and volcanoes. The fact that matter is composed of atoms tells us that individual atoms in the earth system—in a grain of sand, a gold ring, or a student's most recent breath—have been cycling for billions of years.

Living things are arguably the most complex systems that scientists attempt to understand. But we believe that five basic principles apply to living systems: All are based on chemistry. All are made up of cells. All use the same genetic code. All evolve by natural selection. All are interconnected.

In developing and teaching a course based on these principles, we have found that we can bring science alive



for students because any topic touching on science and society can illustrate the general principles. Any specific event—an earthquake or volcano, a flood or drought, a comet or eclipse—involves the basic laws. Discoveries of new materials, reports of environmental dilemmas, or breakthroughs in medical research can amplify the core concepts. Similarly, any question from the class can be answered in part by referring to a basic principle.

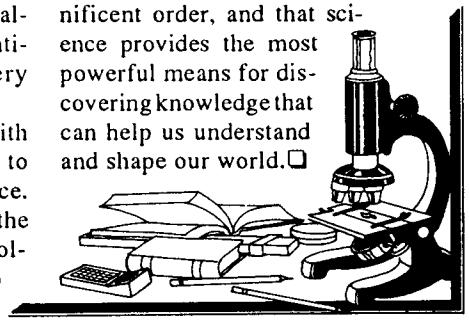
Although the need for courses based on unification of the sciences seems clear, we frequently hear that no one will be able to teach them. Underlying that objection is the belief that only physicists can teach physics; only biologists, biology; etc. If that is so, we must face the sobering possibility that most scientists are themselves scientifically illiterate outside their own specialties.

If colleges are to produce scientifically literate graduates, at least a few members of the science faculty must be prepared to teach general science courses. University administrations always have been quick to reward science professors who do good research and produce a few talented Ph.D. graduates every year. Now, they must be just as quick to reward the generalist who produces a class of scientifically literate nonscientists every year.

Few scientists enter teaching with the broad knowledge necessary to present a general overview of science. But all should be able to learn the basics of other disciplines.Some colleges may tap senior scientists, who have the most breadth of experience, to present this material. Others may call on younger faculty members. In either case, if they were given a few incentives such as paid study time and weight in the promotion process, many science faculty members would embrace a chance to broaden their horizons.

At George Mason University, eight science professors—including tenured faculty members from physics, chemistry, geology, and biology—voluntarily attended a general science course for a full semester to prepare to teach a core science course. They knew that their efforts were important for the educational program of the university, and their efforts were recognized and supported by the administration.

Science educators have created a system that alienates students from science from their earliest years. At each grade level, the accumulated vocabulary and data winnow out more students. By returning to general science courses for all students, colleges can in some measure reverse that trend. Our goal must be to produce college graduates who can see that scientific understanding is one of the crowning achievements of the human mind, that the physical universe is a place of magnificent order, and that science provides the most powerful means for discovering knowledge that can help us understand and shape our world.❑



Introducing Religion into the Classroom

By Thomas W. Goodhue
From *The Christian Century*

WHEN the U.S. Supreme Court banned mandatory prayer in public classrooms, it also upheld the constitutionality of teaching about religion, but it seems to have taken nearly three decades for many teachers, administrators, and textbook publishers to get the message. Finally, the tide seems to be turning.

In 1988, a coalition of organizations ranging from the National Conference of Christians and Jews and the National Association of Evangelicals to the American Federation of Teachers and the National School Boards Association issued *Religion in the Public School Curriculum: Questions and Answers*, which endorses teaching about religion. This group also issued *Religious Holidays in the Public Schools: Questions and Answers*, with ways educators can treat holidays in both a constitutionally permissible and educationally sound manner.

A new consensus seems to be emerging on the goals of instruction about religion. The first of the two publications just mentioned suggests: (l) the school may strive for student *awareness of* religions but should not press for student acceptance of any one religion; (2) it may sponsor *study about* religion but may not sponsor the *practice of* religion; (3) it may *expose* students to a diversity of religious views but may not *impose* any particular view; and (4) it may *educate* about all religions but may not *promote* or *denigrate* any religion.

The holiday brochure argues that "if the approach is objective, neither advancing nor inhibiting religion, it can foster understanding and mutual respect among students within and beyond the local community." This sort of education is not value-neutral (as if anything were); it promotes cross-cultural understanding, tolerance, and empathy. It examines American religious diversity without suggesting that all faiths are the same.

One way teachers are attempting to achieve this is by dealing with reli-

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