mate subjects, with the use of ethical principles similar to those guiding human experimentation. Such a project would also heighten awareness of the urgent need to protect and conserve these endangered hominoids who are so closely related to us.

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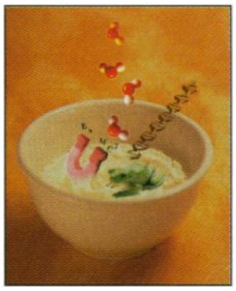
Science Education Reform

In their important suggestions for the reform of science education ("Coherence in science education," Policy Forum, *Science*'s Compass, 10 July, p. 178), Marjorie G. Bardeen and Leon M. Lederman note that hundreds of studies, panels, committees, and analyses of international tests have confirmed "the deep systemic problems facing our educational system." There is considerable uniformity among these studies in conclusions about what is wrong and what is needed to fix the system. The solutions, however, tend to suggest only that we do better what we are now doing. If any of the suggestions are heeded, the changes are generally marginal and ephemeral.



What goes into a good scientific education?

Having been involved in many of these efforts since the mid-1950s—yes, there was concern even before Sputnik—I continue to feel that we should accept that the present system of science education is essentially bankrupt, as any reading of the evaluations of it suggests, and that dramatically new ways of doing science education should be considered.

No one knows what a different educational system appropriate for the nation's needs might be, and only experimentation with various patterns will indicate what programs in science education will better serve the nation as a whole and the students in the classrooms. One of the appalling defects to be overcome is simply this: almost without exception, there is no place in the kindergarten through grade 12 (K-12) system where students are provided a solid background of information that will enable them to make those sound decisions required by informed citizens in our complex society. In fact, no important human problem for which science and technology may be both a cause and a solution is treated adequately. Some of these problems are the use of natural resources, health care, agribusiness, pollution, worldwide population growth, global warming, and understanding the strengths and limitations of scientific procedures.

As far as these complex societal problems are concerned, K-16 education is largely irrelevant. The reason for this is that the students are presented with little more than the contents of one or several of *the separate* disciplines of science, but the critical step of using the information to consider human problems is rarely taken. Would it be worthwhile to design the science curriculum with the goal of understanding both the natural and the technological worlds that students experience? There must be an acceptance that science courses have to make that major step to relevance. There is quite a gap between understanding the chemistry of combustion and understanding how human societies will solve their needs for energy now and in the future. Students need to know both.

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I was pleased to see the Policy Forum by Bardeen and Lederman and their call for a 3-year high school science sequence. They make a case for a "coherent, integrated" high school science curriculum described as Science I, with a focus on physics; Science II, with a focus on chemistry; and Science III, with a focus on biology.

Bardeen and Lederman state that science education should reflect the "hierarchical nature of science as it has unfolded over the past century." Reflecting on the revelations and advances in science in the last 100 years, we have witnessed a growth in scientific knowledge that was almost unimaginable at the beginning of the century. I agree that it is a necessary goal to strive for a scientifically literate society

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that can understand, even enjoy, the assimilation of scientific knowledge from the traditional disciplines, the interdependence of scientific discovery and technological advances, and the role of scientific knowledge and scientific ways of thinking that will be needed to address the major societal challenges facing the human race. However, I propose a pathway to this goal that is somewhat different from the one proposed by the authors, one that is more strongly discipline-based. Further, I would suggest that if all middle and high schools and their science departments are encouraged to follow the same sequence, the collective result will be improved instruction and a curriculum leading to higher levels of student achievement.

I have just completed 6 months of service as a member of the California Commission for the Establishment of Academic Content and Performance Standards, in which I served as chairman of the Science Committee. The standards adopted by the commission and forwarded to the State Board of Education for review provide grade-by-grade content standards from kindergarten to the 8th grade. Perhaps the most important recommendation is that standards at the 6th grade focus on Earth sciences, at the 7th grade on life sciences, and at the 8th grade on physical science. The standards for grades 9 to 12 are divided into four content strands: physics, chemistry, life sciences, and Earth sciences. An investigation and experimentation strand describes a progressive set of expectations for each grade from K to 8 and one set for the 9-to-12 grade span (The science standards can be viewed at www.ca.gov/goldstandards).

The Academic Standards Commission adopted the grade-span approach to accommodate both integrated science and discipline-based curricula. I think this is a mistake and, although it was not adopted by the Academic Standards Commission, I proposed that all students, having completed the grades 6-to-8 sequence, take biology in the 9th grade, chemistry in the 10th grade, and physics in the 11th grade.

The pending California high school content standards, when listed in sequence as biology, chemistry, and physics, provide the foundation for a coordinated 6-year sequence that offers a number of important advantages. Teachers will have the opportunity to prepare for and focus on one discipline, but should also teach the natural conceptual connections that build up knowledge of the discipline. Students will have received instruction and acquired the foundational principles of physics and chemistry in the 8th grade, preparing them for biology in the 9th grade and creating the early opportunity for them to take advanced courses. A rigorous physics course can be taught using more advanced mathematics by waiting until the 11th grade. This sequence can be augmented in the 12th grade or earlier by a course in the Earth and space sciences and advanced courses in biology, chemistry, or physics in schools that have the capability.

I disagree with the statement by Bardeen and Lederman that in the biology-chemistry-physics high school sequence "the subjects are treated as completely independent and unrelated, to be learned (and forgotten) in the sequence taken." I doubt that this pessimistic assessment is a generally accurate description of even the current situation.

I take the position that the nature of modern science today can only be achieved if we prepare students in the fundamentals of the science disciplines that are most efficiently taught in a 6-year specific sequence in traditional, largely discipline-based courses (Bardeen and Lederman mention this as an alternative approach). Early introduction of the most central concepts is needed, and instruction should focus on the essential core content of science. After all, the many scientists who so enthusiastically endorse the approach called for by Bardeen and Lederman arrived at this "higher" conceptual perspective through traditional, discipline-based instruction.

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Response

We are sympathetic with Moore's insistence that relevance to human goals is essential. Projects that reflect real-world problems must, we believe, be included, and are already richly contained in the standards. Depending on local variations, these may well be introductions or even organizing themes for the core disciplines that incidentally are drawn ever closer together by advances in science. Applications of knowledge to human welfare also provide a bridge to the social sciences and the humanities. But we must be aware of the changing world the students will inherit.

Capturing the interest of students to motivate them to learn the science that they might not otherwise find compelling is not only good pedagogy, it illustrates the process of science. However, urgent social problems and their contexts change. The lesson is to give students the power to face new problems, to find out, to think critically, to examine skeptically. We call this "science thinking." We do not know how to teach this without giving all students a grasp of the core disciplines and their many connections.

As for Seaborg's letter, we certainly agree that a seamless 6-year science sequence (grades 6 to 11), with which, however, mathematics is fairly carefully woven, is an ideal. With an increase to 3 years of high school science in places like Chicago and New York City, Project ARISE (American Renaissance in Scientific Education) focused on grades 9 to 11, hoping eventually to add a fourth year in high school and to influence middle schools. Seaborg favors a disciplinary approach; so do we, although we put more emphasis on the value of interdisciplinary connections. Where we differ is in the sequence of courses. We favor an inverted order. It may be that 8th-grade chemistry and physics prepare children for 9th-grade biology, but if that is sound rationale, then why not continue the logic? Modern biology (as most of the textbooks we have seen agree on) rests on basic physics and chemistry, which are taught more rigorously to high school students than mid-level physical science. We have made a reasonably logical argument in favor of "moderate" reductionism that gives coherence to the scientific disciplines. We agree with Moore that, to make our case, we need far more experience with a physics first sequence, in real schools with real teachers, than the few dozen schools we know about, successful as they are. Finally, we would love to listen to a debate between Moore and Seaborg!

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5200-Year-Old Acupuncture in Central Europe?

The Tyrolean Iceman (*1*), by far the oldest European mummified human body (5200 years old), shows 15 well-preserved tattoo groups on his back and legs, none of which appears to have ornamental importance. The tattoos have a simple linear geometric shape and are located on parts of the body that are not expected to be displayed (*2*). Moreover, several tattoos that would have entailed superficial skin puncture seem to be located on Chinese acupuncture points.

The tattoos were therefore investigated morphometrically, and photographs were subsequently overlayed by topographic representations of acupuncture points (*3*). According to the expert opinion of three accredited acupuncturists (*4*), nine of the 15 tattoos could be identified as being located on or within 5 millimeters of acupuncture points. Five tattoo groups on the back of the Iceman were located in close proximity, or directly over, acupuncture points of the urinary bladder (UB) channel. A close match between the acupuncture point UB 60 and one of the two tattoo crosses near the left, lateral ankle was observed.

The theory of acupuncture predicts that perforation or irritation of the skin at specific locations, the acupuncture points, results in modified function of related, not necessarily adjacent, organs, allowing relief of pain or inflammation.

It is known from computer tomography (*5*) that the iceman suffered from arthrosis of the lumbar spine. Acupuncture points used for treatment of this condition (*3*) coincide with tattoos found along the UB channel.

These findings raise the possibility that the practice of therapeutically intended acupuncture originated long before the medical tradition of ancient China (approximately 1000 B.C.) and that its geographical origins were Eurasian rather than East-Asian, consistent with far-reaching intercultural contacts of prehistoric mankind.