Elementary science education in the United States: how scientists can help

During my early school years, the Second World War was underway, and—as for many others—my view of the world was dominated by this event. Life was relatively simple: there were the good guys and the bad guys, and they did good and bad things, respectively. Only much later did I come to realize how complex the world really is: all too often, good, well-intentioned people establish rules and institutions that end up doing bad things to the people who they are trying to help. So it is with science education in our schools.

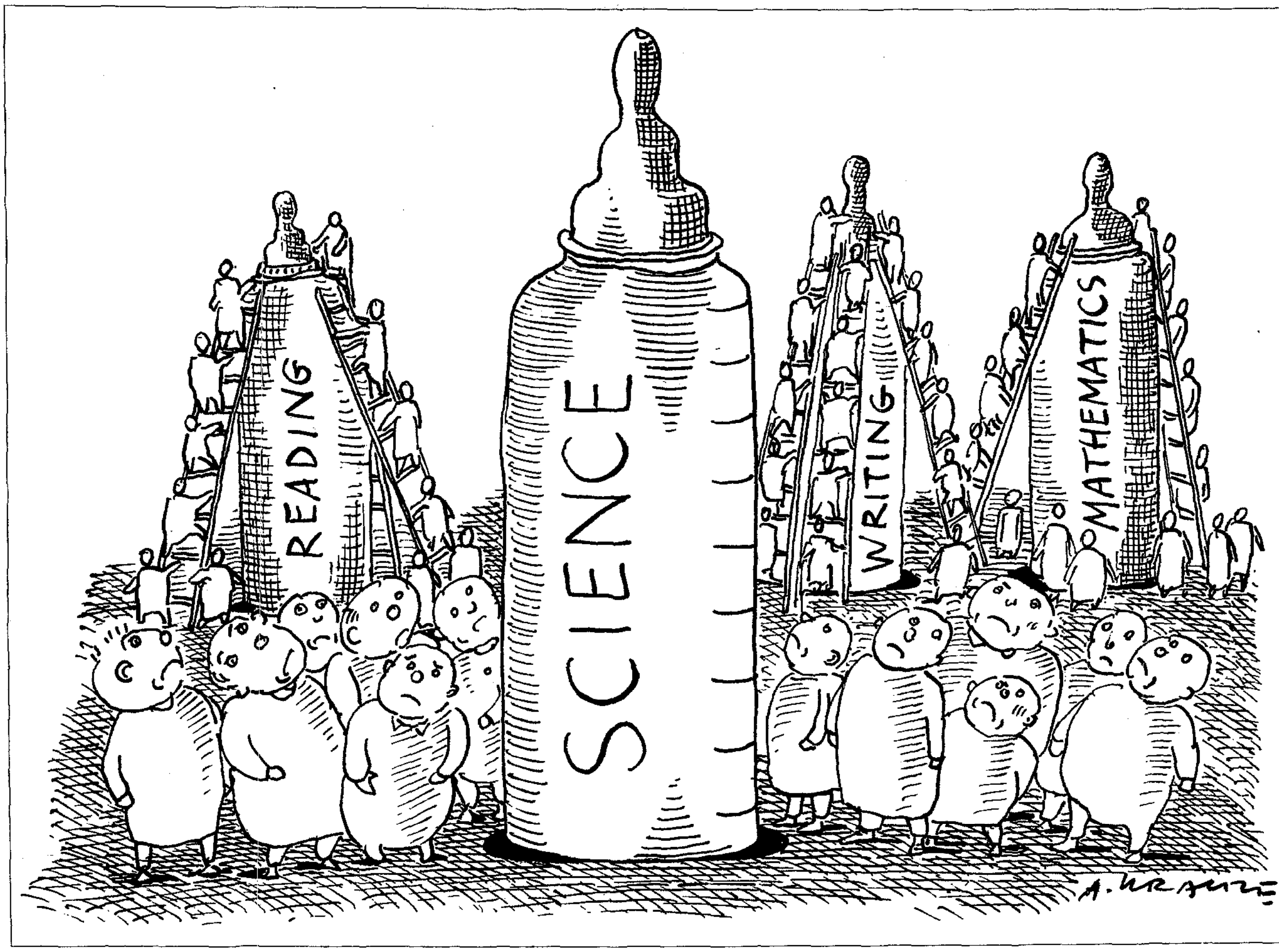
Scientists are puzzle solvers, and the natural world is full of weird and wonderful phenomena that need explaining, providing us with an unending series of challenges. To me, learning to do science is not much different than learning common sense: the tools of modern science are much more sophisticated than the tools of everyday life, but the same type of puzzle-solving—involving postulating hypotheses that are readily tested by experience—is important for success in almost any human endeavour.

I view early science education as education in an important aspect of common sense, that is, in effective solving of the problems that are posed to everyone by the natural world. Viewed in this way, science is clearly seen to be a core subject—like reading, writing, and mathematics. A wise friend who has been worrying and writing about science education for more than forty years, Professor John A Moore of the University of California, Riverside, argues that science education should comprise at least twenty percent of each year's curriculum for grades kindergarten through 12 (ages 5–18). By science education, he means hands-on experience in puzzle-solving that builds on the natural curiosity of children and helps them to make better sense of their world. As there are twenty five hours of instruction in a typical school week, Moore would require five hours a week of this type of science instruction. Yet, it has been estimated that less than one percent of the elementary students in the United States (ages 5–11) receive as much as two hours per week of hands-on science instruction in our schools.

The reasons for the inadequacy of the science education that our children receive are many, but a number are particularly worth mentioning. First, in science courses at many levels, what is easy to test by science exams perverts what we require our students to learn. The result is an emphasis on 'science names' that is inappropriate at the college level, and completely misguided at lower levels. In many middle schools, for example, students are expected to memorize hundreds of one-line definitions of such complex entities as the Golgi apparatus or the mitochondrion, while lacking any basis for understanding what they are. Second, most elementary teachers have an aversion for the type of science that they were taught in school, and they know almost nothing about science as a puzzle-solving exercise. Third, designing interesting, age-appropriate science investigations for young people is an art that requires both an understanding of science and an understanding of how students learn. There are very few professional curriculum developers who are able to do this effectively. It is unreasonable to expect individual teachers to be able to design such science lessons by themselves. Fourth, doing meaningful hands-on science investigations in the classroom often requires special materials that are unavailable to an elementary teacher. In the United States, obtaining the funds needed to correct this situation depends on having an effective 'science lobby' in each school district, given the political manner in which most budgetary decisions are made. But in most districts, there is no effective lobby for science. Finally, even in those rare cases where all of the above problems have been overcome by an enlightened school system, reading a story about whales to the class as the 'science lesson' may be much more appealing to a harried teacher than dealing with the mess and extra work caused by a hands-on science experience.

So much for the bad news. The good news is that there is a tremendous momentum building to change things. Nearly everyone in the United States, from President Bush on down, agrees that a quantum leap is required to improve the science education in our schools. Much of this impetus for change comes from the conviction that we need to produce a much more science-oriented workforce if we are to compete economically with Western Europe and Japan—perhaps not the best of reasons to care deeply about the education of our children, but nevertheless a useful one.

I believe that scientists have a crucial role to play in precollege science education reforms. But it is not easy to know how or where to begin. The natural response of a scientist who wants to help improve science teaching in our schools is to concentrate at the high school level (ages 14–18). Here the science taught is closest to the 'real science' of our disciplines—be it biology, chemistry, physics, or earth sciences. But high school teachers presently face tremendous constraints, including the need to teach for state and national tests that stress a broad (and necessarily superficial) coverage of science, 45-minute periods that are too short for meaningful laboratory sessions, and the difficulty of reaching students who have already acquired a strong distaste for what was called science in their early school years. Many of us with



experience in school systems have therefore come to the conclusion that the major revolution called for in science education is best accomplished 'bottom up', by starting in what at first seemed to us to be a very alien world—the elementary school.

The advantages of focusing our limited resources on accomplishing systemic change in the science taught in elementary schools include the fact that many of our best teachers are found in these schools, and they teach curious children who are still eager to learn. Moreover, they have one class for the entire day, so that they can schedule the time required for a meaningful hands-on science experience. Of crucial importance, outstanding science units have been developed for teaching hands-on science at the elementary level (by the National Science Resources Center in Washington DC, the Lawrence Hall of Science in Berkeley, California and others). Many of these units are available in the form of kits (containing books and materials) that can be used successfully even by those teachers who lack a science background (the vast majority of teachers). A further advantage is that the curriculum taught is not subject to the types of constraints that presently stifle revolutionary change at the higher levels. Science process, rather than science facts, can therefore be the predominant focus of the elementary years.

At these lower levels, 'hands-on' experience with meaningful science explorations should be a major part of a science curriculum that stresses the presently ignored requirement that the material taught should be interesting. If we can accomplish this, students will arrive at secondary school with enthusiasm rather than fear for science, and their positive experiences are likely to force the development of a similarly interesting science curriculum in the middle and high schools.

Among experts, there seems to be little or no dispute about what should be done to improve science education at the elementary level. What we lack are the will and the resources required to do it. In the United States, school policies are determined by local school districts, most of which lack both the expertise and the impetus for attempting any major change. A revolution in science teaching is likely to require a coalition of outstanding elementary teachers (as a district 'leadership team') with a small team of local scientists. By acting as catalysts, these scientists in each school district, working part-time as volunteers, can make a major difference to the type of science that is taught to our children. Their major role is to create a 'science lobby' to help and promote the real change agents in the system, who are the outstanding teachers. We are indeed fortunate that, despite the many problems in our schools, most school districts still contain such large numbers of talented, dedicated teachers. It is these people, and the children whom they teach, who badly need our support.

The scientists with the above role can come from either industry or academia, but in either case they must be well-informed and prepared in order to play an effective part. They will need a master teacher to introduce them to both the pedagogy and the content of elementary science teaching. For example, teaching at this level involves dividing students into cooperative groups of three or four in which the teacher guides science explorations, rather than our standard method of lecturing. The scientists will also need guidance on how to work with teachers and with school districts, and how to help in obtaining the supplementary funding needed for school science. Most of all, these scientists will need to be firmly connected to a network of other scientists like themselves, as well as to science educators on whom they can call for help and advice.

With the encouragement of the National Academy of Sciences, an experimental two-day mini-course with all of the above goals is being offered by the American Society of Cell Biology, just before their national meeting in Boston in December 1991. Financed by a grant from the National Science Foundation, this mini-course is intended to be the first of a series of such courses held in connection with the national meetings of major US scientific societies. The aim is to develop a large cadre of informed and interested scientists, and to network them together with leadership from the National Academy of Sciences. Within the next year, the Academy also hopes to establish a set of local working groups—each composed of outstanding teachers, scientists and science educators—designed to support and inform others in the network, as well as to work in their local area on science education reform. One of the tasks for these groups would be to identify outstanding model curricula, teacher in-service programs, textbooks and laboratory exercises, and then to find effective ways of encouraging their widespread adoption. A second crucial responsibility would be to help create a strong focus at every major university on the education and support of pre-college science teachers. If these teachers are welcomed on all of our campuses—as an integral part of the science community—many more of our students can be expected to become interested in exploring such careers.

The problem we face is a huge one, and there will be no quick solutions. But I believe that a properly organized group of scientists can be effective in catalysing meaningful and lasting changes in this badly neglected area.

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Readers of this article who are interested in obtaining more information about 'hands-on' science kits and curricula for elementary schools should consider joining the network established by the National Science Resources Center (a joint project of the Smithsonian Institution and the National Academy of Sciences) by writing to the NSRC, Smithsonian Institution, Arts and Industries Building, Room 1201, Washington, DC 20560. Worthwhile reading includes: *Fulfilling the Promise: Biology Education in the Nation's Schools*, 1990 (National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418), and *Elementary School Science for the 90s*, by Susan Loucks-Horsley *et al.*, 1990 (The Network, Inc., 300 Brickstone Square, Suite 900, Andover, MA 01810).