You Can Lead a Horse to Water . . .

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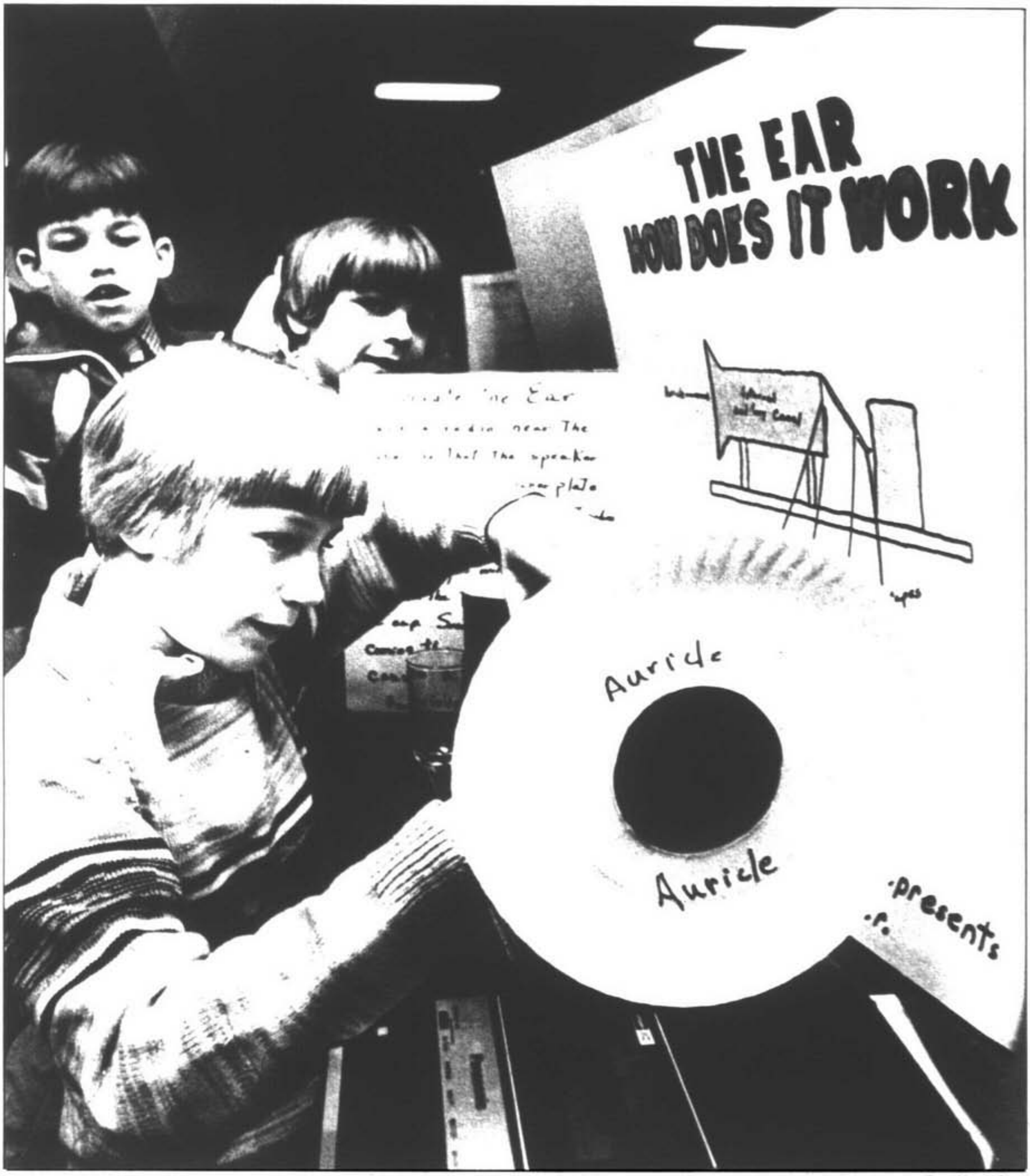
Scientific literacy for all students is an unrealistic goal, but *technological* literacy is both desirable and attainable.

Science education is fashionable again, along with scientific literacy for the masses. It all began in late 1980 with a policy report commissioned by President Carter. In that report, the Director of the National Science Foundation and the Secretary of Education addressed (1) the number and quality of our professional scientists, engineers, and technicians; and (2) the technical illiteracy of most of today's high school and college graduates. The report attracted a great deal of media notice with its inevitable comparison between science education here and in the Soviet Union.

Many hoped the report would somehow trigger increased government support for science education, a hope that was quickly dashed by the incoming Reagan Administration, which began to dismantle the NSF Directorate for Science Education and the Department of Education. What previously had been a matter of concern mainly to the science education community quickly escalated into a national "crisis," with as much grist for the political mill as for concerned educators.

Other commission reports soon took up the chorus. For example, the National Science Board Commission on Precollege Education in Mathematics, Science, Technology, in its initial report, "Today's Problems, Tomorrow's Crises," concluded that the principal concern was a steady decline in student achievement (and participation) in science and mathematics, coming at a time of increasing national need. The



Sister Norma Casey

report also urged increased scientific literacy of all citizens for "full participation in the society of the future." The report of the National Commission on Excellence in Education, less provincial, deplored students' mediocre performance in all disciplines and called for major reforms across the board.

The persistent tone of these reports, together with their political overtones, are bound to provoke substantial changes over the next few years in the style and content of our total educational structure, including science and

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mathematics. One must applaud any genuine movement to improve precollege education generally. But there is a danger that in our rush to correct the perceived deficiencies in science education we may not only repeat the mistakes made during the previous "crisis," but also make new ones.

What exactly is the current crisis in science education? Declining test scores are given as one indicator that we have reached a critical stage. A growing shortage of *qualified* high school science teachers is cited as another.

In practical terms, what are likely to be the consequences of these indicators? The usual response includes: (1) an impending shortage of trained scientists and engineers, and (2) continued scientific illiteracy of our citizens generally, including most of the nation's leaders and decision makers. The first is debatable; the second would be the case irrespective of a crisis. To assert that we currently have a major shortage of scientists and engineers, or that such a shortage is imminent, is a gross exaggeration. Spot shortages exist in a few engineering fields, but in most, supply and demand are in balance, and there are actual surpluses in a number of science and engineering disciplines.[1] Schools operate under a sensitive feedback system that somehow keeps students informed of the current job situation in all technical fields. The supply shifts to meet the demand—with some time lag, of course.

This is an important point that appears to have been ignored in the current "crisis." Many fail to realize that the supply of technically trained individuals in our society is limited not by our educational system but by the marketplace.

Fewer than 10 percent of our precollege students profess a genuine interest in science, and roughly one-quarter of this group actually goes on to become professional scientists and engineers, of which we currently produce about 300,000 per year.[2] The "attrition," if it can be called that, is probably due more to market saturation than to any other single factor. Our present economy couldn't possibly absorb even twice this number, now or in the foreseeable future. But even if it could, there is no reason to believe that the requisite number of students would not turn to science, or that our precollege educational system could not properly prepare them.

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Bear in mind that at most we would have to prepare only 10 percent of our high school students for careers in science. Without going into detail on such expedients as specialized high schools, dual track systems, master teachers, extracurricular programs for science–bound students, it is entirely possible to adequately prepare this number of science–bound students—even with a shortage of teachers—*if* we were to concentrate on the students who are truly interested in science. Most high school science teaching today is devoted to the 90 percent of students who are not science–bound, who enroll in science courses mainly because they are required to do so.

Why do we make students take science courses? Because many people, particularly educators, believe that understanding something about science is the *sine qua non* of an educated person. Yet all efforts to develop broad scientific literacy have failed, including the massive effort that followed Sputnik, and there is no reason to believe that new attempts to achieve widespread public literacy in science will be any more successful. Two reasons for this stand out above others. First, the public remains unconvinced that the effort to gain a reasonable understanding of science is actually worth the prize. Clearly, the average educated adult manages quite well with little or no understanding of science, or for that matter, of mathematics beyond simple arithmetic. Knowledge of these disciplines is not perceived by most people as being essential to either the "good life" or to a successful career outside of science. Hence there is no incentive for the average person to become literate in science, either for economic reasons or because of peer pressure.

Second, scientific literacy is difficult to achieve because we have not learned how to teach science to the nonscience student in a meaningful yet painless fashion. For the most part, the kind of science we teach may appeal to the professional scientist and to science–bound students, but does not make a lasting impression on the average student. This is understandable, since most of the basic concepts of science do not accord with our everyday common sense experience. Students are asked to accept on faith the seemingly bizarre models and explanations that constitute the foundations of modern science. And to make matters worse, the native language of science—mathematics—is foreign to most students. There are no common sense counterparts for these models, nor are there likely to be any in the future because the ultimate explanations in science are at the molecular and sub–molecular levels, where reasoning by analogy with our everyday experiences requires an enormous stretch of the imagination. In the face of all these obstacles, seeking even a small degree of enduring scientific literacy in our general population becomes a forlorn hope.

Scientific vs. Technological Literacy

How, then, should we address the problems posed under the guise of a crisis in science education? Suppose we had better high school science teachers, improved laboratory facilities, another round of new curricula. What might be the end result? Probably test scores in science would improve, at least for non-science-bound students; but we know from past experience that this is no valid indicator of future scientific literacy. Also, such changes probably would provide the science-bound student with a more fulfilling educational experience; but as we have seen, they would not result in more scientists and engineers *unless* the market demand for such personnel increased dramatically.

The one positive result that hopefully will emerge from the present "crisis" is a sober reevaluation of our goals in science education. Should we continue trying to achieve the elusive common literacy that for so long has been the implied objective of minimum science requirements in our high schools and colleges? Or should we be realistic and aim at a target that may be easier to hit—namely, technological literacy?

Science, engineering, and technology are related but distinct enterprises. In the public mind, however, they are generally lumped together under the broad heading of "science." At least part of the problem of scientific literacy probably can be traced to just this confusion in terms. The overall enterprise generically known as "science" begins in the real world with observation and in the end returns to that world in the form of technology, for example, in the form of real things. The beginning and end are easy to relate to because they conform to our everyday experiences. We all "observe" nature to some degree and we all have direct contact with the end products of science—with the machines and structures and manufactured products that derive from its technology.

Between the two lies the strange and exciting world of science—where one seeks to understand the underlying causes of natural phenomena. The problem, however, is that in seeking such understanding we often must resort to abstractions that do not seem to conform with the real world, with our practical, common-sense perceptions of that world. Stated simply, where science seeks an ultimate understanding of the natural world, and engineering seeks to apply such knowledge to practical needs, technology deals with the tools and techniques—the methods of producing the end products for a modern industrial society. One does not need to understand the ultimate causes of things to appreciate their end uses.

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Most students, and the public generally, relate more easily to technology than to science simply because their daily contacts are with the products of technology. Some call it "applied science," others may think of it as "practical science," but whatever name one gives it, technology has the advantage over pure science of keeping the student in touch with the "real" world.

A properly designed technology curriculum is not, as some may think, simply a course in "kitchen chemistry" or in the workings of a radio or gasoline engine. It is far more encompassing. The primary objective of such a curriculum should be to make students feel comfortable with their total environment, not to regard the end products of our scientific enterprise with awe or suspicion but to understand enough about them to have a sense of being in control—to know their capabilities and limitations, and to appreciate their dangers.

The technological literate will know what to expect of the machines that do much of our work for us; what human jobs they can replace in our society and what they cannot be expected to do economically. The technological sophisticate will also be aware of the subtle distinction between knowing what can be done and what is beyond reasonable expectation. When assessing the vistas of technology, it is often better to know its limitations than its prospects.

Then there are the pervasive societal issues that are said to have a scientific base, but which more often than not are really based upon technology. Our technological literate will at least be conversant with the technological bases of such issues as nuclear power, environmental pollution, genetic engineering, robotics, and the like and, hence, will not be easily misled by demagogues or by sensational reporting.

Times are changing. We are moving into a more pronounced technological age in which technology promises to touch more closely the lives of most people. The workplace generally will expect from its employees a better understanding of technology than ever before. Thus, where there were few, if any, incentives in the past for one to become literate in science, there will be compelling reasons in the future for widespread technological literacy.

If the current "crisis" in science education prompts nothing more than a major review of our objectives in this field for the general student, it will serve its purpose admirably. There is no real need for general scientific literacy; nor do I think it attainable. Let us now forget the platitudes about scientific literacy and move toward the more realistic goal of technological literacy. Otherwise, we should seriously consider eliminating all science requirements for the general student. Forcing students to take science is like leading a horse to water. There is no assurance that either one will actually drink. □

[1] "Labor Markets for New Science and Engineering Graduates in Private Industry," National Science Foundation (NSF 82-310), June 1982.

[2] "High School and Beyond," National Center for Educational Statistics (unpublished study reported in *Education Week*, July 27, 1983). See also data cited by Paul Hurd on percentage of high school seniors taking advanced placement tests in science: "Science and Mathematics in the Schools: Report of a Convocation," National Academy of Sciences, 1982.