

EDUCATING SCIENTISTS AND ENGINEERS

by L. A. DuBRIDGE

EDUCATION, of course, begins at birth. By the time a youngster starts his schooling, he has learned far more than he will ever learn again in an equal time. He will have learned to speak, to understand, to listen, to remember, to form habits, to have a moderate awareness of what is taking place in the little world that surrounds him.

He has probably even learned to add $2+2$. Unfortunately, that is about as much mathematics as he is likely to learn for several years. Because as soon as he learns simple addition, subtraction and the multiplication of small numbers, he begins to hear on all sides about how *hard* mathematics is. Learning the multiplication table does take time, and he soon gets the idea that doing higher mathematics means just adding and multiplying bigger and bigger numbers. So pretty soon he agrees that math is a tough and boring subject.

What a shame! For higher math has nothing to do with big numbers. Albert Einstein probably had more trouble balancing his check book than most of the rest of us. Algebra, geometry and calculus are exciting adventures into methods of human thought. And the elements of these subjects are not hard. The speedometer on your car is continuously performing a simple operation of differential calculus—measuring the rate at which you are traveling. And the odometer or mileage indicator is doing integral calculus—adding up the distance you have travelled. That's all there is to it! And young people ought to be learning these things at the age of 12 or 14—not waiting until they are sophomores in college.

One of America's most costly illusions is that mathematics is tough and only a few people can do it—and that only a few people *need* to know it. Only a few

people *do* need to know Fermat's last theorem. But everyone should know that the energy of an automobile going 60 miles an hour is four times as great as that of one going 30—not just twice as great.

In any case, the first great barrier to producing more and better scientists and engineers is the feeling widely shared by parents, students and many teachers that mathematics—that is, simple quantitative reasoning—is a tough, technical, narrow, specialized subject that should be avoided at all costs.

Over in Soviet Russia every high school graduate has had 10 years of math (including calculus) plus 5 years of physics, 5 of biology, 4 of chemistry and a year of astronomy! Now I am not an advocate of doing something just because the Russians do it. But when we note that only 10 percent of all high school graduates in the United States have had any physics and chemistry—and that only 3 percent have gone beyond plane geometry—it is not hard to understand why the Russians produce twice as many engineers as we do—and also why we are not likely to catch up to them very fast. Incidentally, the Russians also awarded 8100 PhD degrees in science in 1954, compared to something like 5000 in the United States—and their PhD degrees are every bit as good as ours, too!

Once an American boy has overcome the barriers to learning a little physics and math in high school he can—if anyone has thought to mention the possibility to him—undertake a college course in science. There are many good engineering and science schools in the country—and they are spending a good deal of time and money trying to tell high school students that they don't have to be long-haired freaks in order to be scientists; that science is fun; and that there are plenty

**Some cogent comments
on some favorite American illusions
—and an indication of how costly these illusions are.
An excerpt from a recent speech.**

of good jobs open in industry, in government and in education.

This campaign, with the help of the ever higher salaries being offered, is beginning to pay off, and the number of young men of talent who are entering courses in science and engineering is gradually increasing. At Caltech we have 1400 applications for admission next year, and we can accommodate only 180 in the freshman class. Naturally, we will try to pick the very best of the applicants, but all the rest will be admitted at some other school. We do not yet have a shortage of facilities as is the case in medical education.

Now what kind of an education should our budding young engineer seek? There are many possibilities available. First, of course, he will have to find a college which will admit him—that is, whose standards match his talents. There is no use blinking the fact that not all colleges maintain the same standards. They shouldn't—for we need trained talent at all levels. Just because a man doesn't make an All-American football team is no sign he will die of T.B. Everyone fits his physical activities to his strength and ability. It is a good idea to do the same thing in the intellectual field—neither trying to stretch beyond one's reach nor being willing to coast without maximum effort.

That is another great American illusion—that it is all right to talk quite frankly about a boy's physical prowess, or lack of it, but never to admit there are also different degrees of mental skills.

But aside from differing academic levels, there are many choices as to the kind of engineering education that is desired.

Caltech introduced two reforms back in 1921. One was to bring research and teaching together in an at-

tempt to stimulate the development of creative talents. The other was to recognize that engineers needed to be aware of some things outside their special field of study and should give at least a quarter of their time to non-scientific studies—literature, history, economics, philosophy and other humanities and social sciences. This was a great new departure in 1921; it is common practice in most engineering colleges today. The idea that an engineer is necessarily a narrow-minded technician is as dead as the dodo. The modern engineer has had an introduction to the world of art, letters and human beings.

This has led to a curious overswinging of the pendulum of education. After it was admitted that engineers should have some humanities, some began to say that it is better for a boy to take *all* humanities. A number of people are going around the country saying we should go “back to liberal arts”—by which they mean to abandon the study of science.

I was brought up to believe that science was one of the liberal arts and that no one was fully educated unless he knew *something* about the physical world in which he lived.

In any case, the present-day need is for well educated scientists and engineers—men who have mastered their subjects, but who have had an introduction to and acquired an interest in other intellectual pursuits. The dangerous illiterates of modern America are not the narrowly educated scientist, but the hosts of supposedly well educated businessmen, lawyers, politicians and executives who are guiding the development of a modern social, political and economic system without any knowledge of the scientific principles on which the whole of modern industry and technology is based.