The Federal Laboratories and Science Education

By playing a greater role in education, Big Science can diminish the manpower shortage it has created.

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One of the most telling criticisms which has been leveled at Big Science is that it makes unreasonable demands on the nation's technically trained manpower. Though nothing may be intrinsically wrong with our spending 3 percent, 5 percent, or even a larger percentage of our gross national product on science (our present science budget is $16 billion—a figure that includes construction of new facilities, which amounted to $2 billion in 1961), serious doubts arise as to whether we can properly man such an effort. I shall not discuss here whether such enormous preoccupation with science is good or bad. I shall assume that we have our Big Science, and that we must do our best to live with it; this means that we must provide many more highly trained scientists than we now have. I shall argue that Big Science, by weaving itself intimately into the fabric of science education, can help alleviate the manpower shortage which Big Science has created.

Is There a Shortage of Technically Trained Manpower?

There can be little doubt that we are suffering from a shortage of highly trained scientists and engineers. The clearest evidence for this is that our operating budget for science has increased since 1950 by a factor of almost 5, whereas the number of Ph.D.'s in science and engineering has increased by only a factor of 2 (from 45,000 to 87,000) in the same period. I know of no evidence to show that our people are smarter now than they were a decade ago; we merely heap more money on them, and therefore we use each dollar less efficiently.

It is sometimes argued that we spend more per scientist mainly because we ask more difficult questions and because it is more expensive to answer a hard question than an easy one. For example, a 20,000-channel analyzer costs about ten times as much as a 20-channel analyzer, but it yields data 1000 times faster. But this is just the point: we are now in a position where, because of extraordinary strides in automatic data processing, acquisition of data outstrips analysis of data. The fact that we get data faster and process it automatically doesn't mean that we need fewer scientists; it means that we need more. "Science" untouched by human brain is not science: the revolution brought about by automatic acquisition and processing of data cannot be allowed to squeeze out the one really essential ingredient of science—human thought.

Before considering ways of increasing our supply of scientists we must ask whether the shortages we have mentioned are bona fide, or whether the trouble is, not that we have too few technically trained people, but that we use the ones we have inefficiently. Perhaps by using our scientists more efficiently we can make the problem of manpower shortages go away.

The main difficulty in such an approach is that science is inherently inefficient. Most scientists spend their lives without ever making a monumental discovery; a portion of their time is necessarily wasted in that, when they try something highly original, more often than not it is wrong, and when they try something safe, more often than not it is relatively unimportant. There is an inherent inefficiency in science's search for truth that we can never hope to eliminate.

This is not to say that we use our scientists as efficiently as the inherent anarchy of scientific research allows. The commercially competitive atmosphere in which much of our Big Technology is developed certainly has in it elements of wasteful frivolity and duplication of effort. Or again, failure to be nimble in research installations—particularly slowness in redeploying manpower as new needs develop—leads to waste. Just how large such wastes of technical manpower are has never been estimated. I believe that they are large, but that there is little we can immediately do to eliminate them. The bad effect of wasteful use of scientists is more likely to be mitigated by creating more and better scientists than by greatly increasing our efficiency in using the scientists we have.

Direct and Derived Shortages

The bona fide manpower shortages—that is, the shortages which are not attributable to inefficiency of operation—are of two kinds: direct and derived. A direct shortage appears in a field whenever the federal government decides to sponsor much additional work in that field. The decision to send a man to the moon creates a shortage among people versed in the art of sending men to the moon—rocket experts, space biologists, and the like. Right now the federal government has before it, in the form of reports to the President's Science Advisory Committee, proposals to increase the national effort in atmospheric science, in oceanography, and in high-energy physics. When such support is provided, it will add to the demand for scientists in these particular fields. For example, the yearly output of Ph.D.'s in atmospheric science that will be needed to man the expanded program in that field by 1970 is estimated to be 4.5 times larger than the number turned out in the field in 1961.

Direct shortages are, in principle, not too hard to deal with, since in our age of scientific-administrative sophistication we generally give money for training at the same time we give money for achieving a technical goal. For example, the U.S. Atomic Energy Com-

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mission, largely at the behest of Admiral H. G. Rickover, established an excellent specialized training program in reactor engineering as early as 1946. Many of the graduates of this program are now active participants in the country's reactor development program.

More intractable are the derived shortages. When the federal government pours money into a certain field of science or technology, that field acquires glamor as well as funds for fellowships and training. Young talented people tend to go into these fields and to desert the older, less glamorous ones —not because the older field is less important to the national welfare but because it is old hat and offers fewer fellowships. Often the older field will have too little political punch or too few aggressive salesmen (or in some cases too many practitioners who like the extra money they make when there is a shortage of trained personnel) to allow strong counterpressure in favor of that field to grow.

A particularly unfortunate result of such distortion of our scientific emphasis is the shortage of students in medicine, much of which seems to have come from the great emphasis on other scientific fields. We now have 132 M.D.'s per 100,000 population; merely to maintain this ratio (which is believed by many observers to be inadequate) would require an increase in the production of M.D.'s from our current 7081 per year to 11,000 per year by 1971. What is deeply alarming is that the number of medical-school applicants has held fast at about 15,000 per year since 1953, even though our population increased by 13 percent in this period (*1*). The number of first-year medical students with college records of A was 21.1 percent in 1953 and 13.4 percent in 1960.

Many of the dangers of Big Science are illustrated by the induced manpower shortage in medicine. We divert our attention from the important to the glamorous; from the man on earth to the man in space. We set in motion surges of manpower away from the necessary tasks toward the fashionable tasks; we try to eat cake when it is bread that we need for nourishment.

Do we have potentially enough people to allow us to eat our scientific cake as well as our bread, to carry on our development by the inefficient but, on the whole, desirable competitive system? According to a recent National Science Foundation report, only one out of 20 of the most intelligent 1 percent of our "doctoral age" young people now gets a doctorate in science (*2*). To increase our scientific population from the present 1.4 million, of whom 87,000 hold doctoral degrees, to an estimated 2.5 million with 187,000 doctorates by 1970 would still tap less than 10 percent of the population innately qualified to pursue successful careers in science. To achieve these goals is a matter of tactics—of deploying new education resources, and deploying them fast. It is my belief that within Big Science itself, particularly within the big federal laboratories, we have an education resource which can be mobilized quickly to train a sizable number of the needed people.

Role of the Federal Laboratories in Science Education

Since their inception, the large federal laboratories, particularly the national laboratories of the Atomic Energy Commission, have been concerned with science education. The laboratories have encouraged science professors in neighboring colleges and universities to use the magnificent and often unique facilities of the large laboratories. For example, at the Oak Ridge National Laboratory each summer we have an influx of about 60 science professors who participate in the work of the laboratory and go home with new viewpoints on current scientific subjects. We invite selected undergraduate students to spend the summer as junior scientists. We have, on the average, 50 or more postdoctoral scientists at the laboratory, each of whom spends a year or two as a research associate. Each year Oak Ridge scientists give 200 "traveling" lectures at colleges and universities in the area. A few graduate theses are done at the laboratory by students from neighboring universities who come as Oak Ridge Institute of Nuclear Studies fellows. All these activities in general scientific education go on in addition to our specialized training activities, such as the School of Reactor Technology and the health physics training program.

Over the years the effect of these educational activities has been massive. There is scarcely a science department in any of the southern universities which has not felt the influence of the Oak Ridge National Laboratory's existence. The laboratory can claim to have participated actively in the postwar scientific renaissance of the South.

But I believe that this somewhat peripheral involvement of the national laboratories in education, good as it has been, does not go far enough—that in the present stage of the scientific manpower crisis nothing less than direct participation of the federal laboratories in graduate, and possibly even in undergraduate, general scientific education is necessary.

The large government laboratories employ some 5 percent of all the science Ph.D.'s in the country. These scientists have been called "scientific eunuchs," since they spawn very few scientific offspring—students. Yet if this cadre could be brought into the educational stream, our country's capacity for turning out Ph.D.'s in science would jump by a significant percentage. Beyond this, the big laboratories have their share of outstandingly brilliant scientists—people who can hold their own in any scientific circle. Graduate science training in conjunction with the best of the big laboratories ought, therefore, to be very good training; such centers would be centers of excellence, not merely additional facilities.

The possibility that the federal laboratories might participate directly in graduate education was discussed in section 11 of the report of the President's Science Advisory Committee Panel on Basic Research and Graduate Education, "Scientific Progress, the Universities, and the Federal Government" (*3*). The main point made in this report was that basic research and graduate science education ought to be closely interwoven. Since the federal government pays for, and therefore has responsibility for, most of the country's basic research, it must bear a responsibility for the institutions in which most of the basic research is done—the universities. This responsibility includes support of administrative overhead and of fellowships and the like—in short, support of science education at the graduate level as well as support of basic research. There are two symmetric routes to achieve this aim of encouraging both graduate science education and basic research. On the one hand, one can start with a good school and build up its basic research; or one can start with a basic research institute (a federal laboratory, for example) and adjoin to it a good graduate school. The former scheme is the one traditionally followed in our country. It is, however, the latter scheme which I propose here.

What are the advantages and the disadvantages of making our federal laboratories look very much more like graduate science schools than they now do? The first and primary advantage is that we could by this means quickly increase the number of centers of excellence in graduate science. Insofar as the number of well-trained Ph.D. scientists producd per year is limited by the lack of first-rate graduate schools, establishing additional good schools would help relieve the shortage of scientists. I estimate, for example, that the three large nonsecret atomic energy laboratories—Argonne, Brookhaven, and Oak Ridge—plus the nonsecret parts of Livermore and Los Alamos could accommodate between 1500 and 2000 doctoral candidates in the physical and biological sciences. This would represent between 5 and 10 percent of the present graduate science population of the United States.

Other advantages would accrue to the centers themselves. First, the flow of graduate students would add zest and originality to the basic research done at the laboratories. Most scientists never work as hard at any other time in their lives as they do as graduate students; to have graduate students around would almost surely raise the accepted norm of hard work in these establishments. At the least, their presence would sustain a general enthusiasm which is so easy to lose, even in basic research, when the research is done year in and year out by the same people, each of whom grows one year older each year. Second, contact with young, beginning students requires the researcher to be a teacher—to order his views; to make sense in detail, not in general; to scrutinize carefully what he takes far granted. It is easy to be content with a partly thought-out view, to take for granted something one understands only dimly because one doesn't have to go over the point in the detail that is necessary in preparing a lecture; many chances to make great discoveries are missed because of this tendency.

The main danger in making our large laboratories over into combination basic research institutions and centers of graduate education is that the job of turning out Ph.D.'s might divert the laboratories from their primary purpose of developing nuclear weapons or reactors or rockets. The testing of a nuclear weapon must be done by professionals; one cannot wait until an inexperienced graduate student catches on. In this respect the two objectives, education and development, would be incompatible. Yet even in applied project work graduate students can be surprisingly useful. At Oak Ridge we have for 15 years had a branch of the Massachusetts Institute of Technology Practice School of Engineering. Candidates for M.S. degrees in engineering spend half a year at Oak Ridge doing a succession of small, but useful, development jobs. We find these bright young people very helpful to us, and I think most of them learn a great deal.

But the graduate students would be involved, in any case, mostly with the basic research at the large laboratories, and this work usually has no deadline. Even the laboratories with the heaviest programs of applications, such as the Atomic Energy Commission's weapons laboratories, do much basic research. The old distinction between the university laboratories and the federal laboratories, one being concerned almost exclusively with basic and the other with applied research, is very blurred at present (*4*). Both universities and federal laboratories do applied and basic research now. The basic-research sector in the laboratories is so big that the laboratories could, if necessary, offer ample opportunities for thesis work in basic science alone. What the students would bring to the basic research in added originality would, I believe, offset any loss in the volume of basic research.

Ways and Means

What I am proposing is nothing less than a gradual conversion of our big federal laboratories, wherever possible, into M.I.T.-type institutions—into research institutions which participate integrally, not peripherally, in educating Ph.D.'s in the sciences. The exact mechanisms for accomplishing this change will vary from institution to institution. The most direct and most drastic is that of converting the existing research institutions into universities. This has been done at the Rockefeller Institute, which is now called the Rockefeller University and is a graduate school chartered as a degree-granting institution in the state of New York. The conversion of Rockefeller Institute to Rockefeller University was relatively simple, since the institute was a private institution which happened to have been born rich.

To make such drastic transformation in the federal laboratories would mean that the federal government would have to establish federal universities. This is something which, except in the case of the specialized Service academies, we have been unwilling to do. Yet the time may be at hand when we must reconsider this position. The federal government has by its lavish support of Big Science created a manpower crisis, both direct and derived. One can argue that the government has responsibility for the educational consequences of its decision to expand research not only in reactor or rocket development but also in basic science, and that every available or potential educational resource must be mobilized, not only the traditional ones—that is, the universities. Federal support of academic ventures (plus some research overhead) at the existing federal basic-research establishments makes as much sense as federal support for basic research (plus academic overhead) at existing universities.

Much can be done short of establishing federal academic science institutes. One scheme which appeals very much to me is for the big laboratories to set up joint institutes with existing neighboring universities. The general plan would be to make the very best basic research scientists at the federal laboratories professors at the universities. These individuals, if carefully chosen, could convert an average institution into a true center of excellence—if not in the 99th percentile, still in the 95th percentile. The special professors would spend, say, half of their time at the university and half at the laboratory; they would be faculty members who happen to do their research at the laboratory. The time they spend in teaching and away from research would be compensated by the influx of graduate students and general improvement in research atmosphere of the laboratory.

In addition to the full professors, a much larger fraction of the laboratory staff would be designated research associates. The associates would supervise, in detail, the thesis work of the graduate students, probably in close collaboration with the special professors. Although the research associates would be available for occasional teaching, they would not be expected to teach regularly. Again, the loss in efficiency which a research associate's work suffers because he must have graduate students would be compensated by the stimulation, not to say prodding, which he derives from contact with students.

There are sticky difficulties in getting such joint university-laboratory schemes going; the worst is figuring out how to pay the jointly appointed professors.

Here I believe the federal government could take the lead. It could state, as a matter of broad federal policy, that the government views such arrangements with favor, and that federal laboratories can make their people available for educational work as part of their regular jobs. The laboratory would be reimbursed by the cooperating university for this service, but at a rate which the university could afford. I believe this is a matter that should be taken up by the Federal Council of Science and Technology, and that a general statement approving such arrangements throughout government ought to be made.

Lesser degrees of involvement may be indicated in special cases. A great extension of the policy of granting sabbatical leaves for academic teaching, by the federal laboratories, paid for at least in part by the government, and by industrial laboratories, paid for in part by the industry, would increase the nation's science teaching staff significantly. One need not confine the teaching to graduate level; many industrially as well as federally employed scientists could profit by occasionally going through the intellectual discipline required for proper teaching of even undergraduate science. Is it too much to hope that industries, to say nothing of the federal government, will appreciate the long-term advantage they get from allowing their scientists to participate in teaching, and that they can be persuaded to pay part of the bill? Other possibilities for interweaving the academic and the nonacademic scientific communities will surely present themselves.

The proposal to recast the federal laboratories into combination graduate schools and research institutions is likely to be received with suspicion—in particular, perhaps, by the academic community, which might see in such a move an encroachment on the proper domain of the universities. Yet the realities of the present age of Big Science cannot be ignored: the enormous public support of science has converted our universities, in varying degrees, into centers of Big Science. Many universities can no longer claim to be primarily "educational" institutions in the traditional sense. The situation is symmetric: if the graduate schools have attached federal laboratories, why should not the federal laboratories have attached graduate schools? What seems to be emerging, in this interpenetration of the academic and nonacademic worlds, is a kind of hybrid which undoubtedly hurts the sensibilities of our traditionalists, both in education and in research, yet which appears to me to be inevitable. Under the circumstances I would hope that both communities, the academic and the nonacademic, accommodate gracefully and work together for the common goal: the strengthening of our country's science, and, one hopes, the improvement of our general welfare. To quote the President's Science Advisory Committee report (*3*), in this effort to find better connections between the two communities, "the right note, we think, is one of hope, not fear. . . ."

References and Notes

1. The number of medical-school applicants reached a postwar peak of 24,000 in 1949. Another, much smaller, peak of about 16,000 was reached in 1957, probably the aftermath of Korea [*J. Am. Med. Assoc.* **178**, 597 (1961)].
2. "Investing in Scientific Progress," *National Science Foundation Report No. NSF 61–27* (1961), p. 15.
3. President's Science Advisory Committee, "Scientific Progress, the Universities, and the Federal Government" (The White House, Washington, D.C., Nov. 1960).
4. Some observers claim it is difficult, for example, to tell whether Massachusetts Institute of Technology is a university with many government research institutions appended to it or a cluster of government research laboratories with a very good educational institution attached to it.

News and Comment

The Tennessee Case: Notes on the Supreme Court's Decision to Open Apportionment to Judicial Review

It is easy to talk in general terms of the long-range impact of the Supreme Court's decision last week, hard to talk in specific terms. Yet there is no doubt that the decision is going to have a substantial effect on the shape of American politics and, therefore, on the whole range of issues, from funds for basic research to conservation of natural resources, that are regularly discussed here as of special interest to the scientific community.

There is going to be a shift (just how much of a shift is not yet clear) in political power at the state level away from the rural minority and toward the urban and suburban majority, and later and much less emphatically, a shift at the national level. A few minor consequences can be pinpointed: the present overbalance of emphasis in state universities on agricultural problems, for example, is presumably going to be shifted toward emphasis on urban problems as the urban populations win a greater share of power in the state legislatures which control the universities. But the effects which happen to be easy to pinpoint are quite trivial in comparison with the shifts that cannot be pinpointed but will inevitably come. Twenty years from now historians will be able to look back and tell us what happened; all we can be reasonably sure of now is that something significant is going to happen.

To pick out a horrible example of malapportionment: In Florida, the worst-apportioned state, 12 percent of the population elects a majority of one house of the legislature; 15 percent elects a majority of the other house. More important, though, than the situation in one state or another is that the problem is nationwide, and that the malapportionment is consistently in favor of the rural third of the population. As a general rule of thumb, the most recent survey suggested, a vote in a small rural community, nationwide, is worth something more than twice as much as a vote in a big city. If this arrangement were true for presidential elections Nixon would have been elected by a landslide of electoral votes, even though he carried a minority of the popular vote; so would Dewey; Hoover