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Carles E. Falk

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CARLES E. FALK*

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I address you with mixed feelings. On the one hand, I am delighted to be with you and, hopefully, to provide some useful information. I feel that way because activities of science bodies such as yours are vital if science and technology are to remain viable tools contributing to the welfare of our society and if the society is to comprehend fully the capabilities as well as the limitations of science. On the other hand, I must admit that I am not overly comfortable in discussing science manpower in the 70's. Like many topics of current interest, this has two characteristics which unfortunately but frequently go hand-in-hand – importance and difficulty.

A better understanding of the dynamics of science and engineering manpower is of vital importance to the national welfare, institutional planning, and to the plans and hopes of hundreds of thousands of students; yet this topic is a very complex one to deal with, especially at this point in time, because both science and science education are in a period of significant transition. Values are changing; rates of academic and R. & D. funding levels are changing; manpower demand and utilization relationships are changing. It is a very difficult time to appear to be a prophet – which incidentally I do not intend to be. Yet it is a time when incisive manpower analyses pertaining to future demand and supply are very badly needed.

I would like to concentrate here on two specific aspects of the problem: 1) the demand and supply situation, and 2) its implications for higher education.

Supply and Utilization

Let me start with the supply and utilization picture and try to put the topic in its proper perspective. This relates to my earlier reference to prophecy. No one can tell you what the situation actually will be like in the late '70s. Science and engineering students are now in the pipeline. Baccalaureate production can be reasonably predicted for the next couple years and doctorate production for the next four to five years. After that, the nature of motivation of students to enter the field of science and engineering, as affected by such factors as popular attitudes toward technology, student support, employment outlook, and so on, make the picture somewhat hazy. As far as future utilization is concerned, there are so many key parameters which can change on relatively short notice that the situation is even more uncertain. What will be the future state of the national economy? What will be the rate of growth of Federal R. & D. investments? How will national priorities change and how rapidly are these changes going to be implemented? It is obvious that no one can answer these questions with certainty. Predictions, at best, would only constitute educated guesses. On the other hand, this does not mean that we should or can afford to forego analysis. Responsible manpower study groups are making and will be making projections as compared to predictions. Now, I am not playing some kind of a semantics game. There is a definitive difference between the two concepts. A prediction makes the claim that it can forecast events as they will actually turn out to be. Projections, on the other hand, are usually derived from statistical models and an awareness of current happenings and produce a range of possible future situations based on definitive assumptions which should be explicitly stated. Thus, projections can show the effect of different variables and can develop a level of understanding useful in planning and policy determinations.

Several groups or individuals have developed such projections in recent months. Two studies cover all scientists and engineers either by different degree levels or as a heterogeneous group. One of these has been made by Wallace Brode, past President of the American Association for the Advancement of Science and of the American Chemical Society (Brode, 1971); the other one was developed by the Bureau of Labor Statistics and reported in their publication "College-Educated Workers, 1969-80." Two other recent studies have concentrated on the Ph.D. or doctorate element in our science and engineering manpower pool. One was carried out by Allan Cartter, Chancellor of New York University, and this particular analysis concentrates on the supply and demand of Ph.D.'s by academic institutions covering the period between now and 1985. (Cartter, 1971). Another set of studies has been carried out by my division of the National Science Foundation, and these cover in some detail the supply and utilization of doctorates; however, the analyses are carried out only through the decade of the 70's. All of the studies mentioned indicate concern and, while they are not completely in agreement in detailed quantitative aspects, all of them foresee the need for change.

* DR. CHARLES E. FALK is director of the Division of Science Resources Studies of the National Science Foundation, Washington, D.C. He holds the Ph.D. in Physics from Carnegie Institute of Technology and B.S. and M.S. degrees from New York University.

The BLS analysis deals with scientists and engineers regardless of their educational attainment. It does not involve variations of parameters and their possible results, but is based on a number of specific assumptions. The principal ones are:

Between 1968-80 the average growth in GNP, in terms of 1969 dollars, will be 4.3 percent per year,

By 1980, we will be enjoying a period of full employment; that is, unemployment rates will be of the order of 3 or 4 percent,

The U.S. will not be involved in any war. Consequently, Federal defense spending will be at somewhat reduced levels.

National R. & D. expenditures will amount to about 2.9 percent of GNP.

Obviously, analyses as complex as these use numerous other assumptions, but the ones I have mentioned constitute the principal basis for the BLS projections. The Bureau's methodology consists of working backwards from a calculated 1980 GNP, which is then translated into specific goods and services. These are subsequently translated into broad employment patterns in various sectors of the economy, which finally are used to identify likely employment patterns by professional specialties, including various disciplinary groups of scientists and engineers. This determines demand due to growth, to which requirements caused by attrition are added. BLS supply projections are based on degree production projections developed by the Office of Education and various studies carried out or funded by NSF which provide information on past patterns of such factors as: rate of entry of college graduates into the labor force, distribution and activity patterns of scientists and engineers among sectors, etc.

On the basis of these assumptions and methodologies, the Labor Department study comes to the conclusion that by 1980 there is likely to be an overall balance between the supply and utilization of college-educated workers. However, the projections indicate diverse situations among various professions. Thus, they indicate a potential supply significantly *below* employment requirements for chemists, physicists, and medical doctors. While the physicists among you might find this surprising, I would like to remind you that baccalaureate production of physicists during the 60's stayed almost constant and that NSF data for the Fall of 1970 showed that first-year, full-time graduate enrollments in physics have decreased by 16 percent from those of the previous year. The BLS study also indicates that the supply of engineers and earth scientists is likely to be *slightly short* of requirements while the supply of mathematicians and life scientists could be significantly *above* available employment opportunities.

As for our NSF studies, they deal only with science and engineering doctorates. I want to emphasize the term "doctorate" since, as compared to Ph.D., it covers any degree beyond the Masters level except for medical degrees. Our last study, published two years ago, dealt only with the body of doctorate scientists and engineers in toto. We are now in the final phases of updating that study and have tried to develop projections for the period 1969-1980 for doctorates in broad areas of science.

We use the Office of Education projections for undergraduates, which indicate that by 1980 undergraduate enrollments in toto are likely to 55 percent greater. Our own projections show that graduate enrollment in science and engineering will increase by 45 percent by 1980; and doctorate production in science and engineering by approximately 65 percent. Student to faculty ratios are assumed to remain the same as they are today. Attrition rates are based on present actuarial mortality rates and current retirement practices.

The ratio of R. & D. expenditures to GNP is assumed to be either 2.7 percent or 3 percent on the basis that 2.7 percent figure has been the lowest value experienced in the last 10 years and 3 percent has represented the maximum. Employment for replacement or new growth is calculated to reflect somewhat increased ratios of doctorates to total scientists. The reason for this is partially obvious. Past employment practices took place during periods of relative shortages in scientific and engineering manpower, while the current situation as well as our analysis of the 1980 picture seem to indicate, at best, a relative balance between supply and utilization, thus producing a greater availability of doctorates. Incidentally, this trend already has been observable in recent years with respect to the maximum educational attainment of new academic faculty members. The employment rates in non-university and non-R. & D. activities are projected to grow on the basis of recent trends and in the case of the high projections to increase at somewhat faster rates.

Our results are as follows: the projections indicate that, if current trends continue, there is likely to be a slightly greater supply than utilization. However, we also see some initial indications that even our low supply projections may be too high because first-year graduate enrollments have dropped by about 2.5 percent during the past year. Thus, factors of the market place may well control the projected imbalances. Looking at specific areas of science, there are distinct differences. The physical sciences seem to be best off and project to be in overall balance; on the other hand, the analyses show a much more pessimistic picture for engineers and social scientists, with possible significant oversupplies. This may seem surprising, but we are producing annually more than 15 percent of the total number of existing engineering doctorates and, while this ratio is not quite as high in the social sciences, their rate of increase in doctorate production has also been very large in recent years.

Let me now specify one other result of our studies which has important implications for higher education, namely, that it seems very likely that a much larger fraction of new doctorates, as many as 50 percent, will be engaged in non-university and non-R. & D. jobs by 1980.

Before going to the implications of those studies, let me warn you not to confuse need with utilization. In our increasingly complex technological society, we could undoubtedly use productively a much greater number of scientists and engineers than any of the projections indicate. However, as everywhere else in real life, the need is usually considerably higher than what can be realized in terms of available financial resources.

The Current Situation

While I have been discussing long-range projections, it is, of course, impossible to ignore the present situation. Much has been said and written about the oversupply of Ph.D.'s. While a problem exists, I believe it is important to look at it in a rational perspective. There is no question that unemployment of Ph.D.'s as well as underemployment has increased significantly over the last two years. By underemployment I mean the utilization of a Ph.D. in an activity which either does not use his graduate training at all or does not use most of it in an adequate fashion. Now, this is a matter which is very prone to subjective interpretation. If a Ph.D. is employed in any technical activity using his skill and knowledge developed during graduate training, he is clearly not underemployed. Thus, it would seem to be a gross exaggeration to consider a man who has done his thesis research in high energy physics and is working in laser optics as being underemployed. Driving a taxi, on the other hand, clearly is a case of underemployment. However, even such cases have to be investigated carefully to ascertain whether the underemployment is not self-imposed through the free choice of the individual. Similarly, some Ph.D.'s are unemployed by their own choice, such as women who choose to take time to raise families.

Best current information indicates that at the beginning of this year, there were of the order of 45,000 unemployed scientists and engineers; these, however, constitute less than 3 percent of the total science and engineering labor force. As far as science doctorates are concerned, National Register of Scientists data collected in the Spring of 1970 indicate an unemployment rate of less than one percent. A recent survey regarding new Ph.D.'s and postdoctorates, carried out by the National Academy of Sciences, and reported in part by Dr. Handler, the President of the National Academy of Sciences at a recent Congressional hearing, also shows unemployment rates of about one percent for the new Ph.D.'s and about two percent for post-doctorates who have left their universities. The same survey indicates that underemployment, as evaluated by departmental chairmen is about one percent for new Ph.D.'s and 1½ percent for post-doctorates. Clearly, these unemployment rates are considerably smaller than the equivalent total national rate and also smaller than the latest unemployment rate of professional, technical and kindred workers as determined by the Bureau of Labor statistics. All the data represent national averages, and it is very evident that higher rates may prevail in certain geographical areas.

Plight of the Unemployed

As you know, there is concern about the plight of the unemployed scientists and engineers on every level of state, local and federal government, and certain remedial programs have recently been initiated. Thus, attempts are being made to try to cope with the problem. However, as must be evident from the statistics just stated, these problems have been exaggerated by accounts which draw very heavily on anecdotal information and fail to take into consideration the overall picture. The present situation also is heavily influenced by an aspect which is not always recognized, namely, the difficulty of doctorates to locate positions of their liking. Thus, the whole issue of unemployment and underemployment has been greatly aggravated by a mismatch of aspirations and opportunities. Maybe all of us have been guilty of placing research and university careers on too high a pedestal, thus giving the erroneous impression to students that other types of activities such as industrial development, post-developmental work, or teaching in four- or two-year colleges are of lesser importance to society or less self-satisfying. I believe that a concerted effort must be made to correct such a set of values.

Much of the unhappiness of the scientific and engineering community of today is due also to the fact that for 20 years there has never been a period during which there was not a considerable excess in demand for their services. Now that demand and supply have come more than into balance and there exists a slight oversupply, the rapid change of circumstances has produced a certain trauma in the profession.

Implications for Higher Education

Looking towards the future, the projections mentioned earlier seem to indicate that, at best, an overall rough supply-utilization balance is likely to be achieved by 1980 if present trends continue and, at worst, there is likelihood of some oversupply in certain areas. The same projections show that future employment opportunities for a significant number of newly graduated scientists and engineers will be of a nature that would not necessarily match the aspirations of recent graduates and for which the current type of training will not necessarily have been optimum. Thus, these projections lead necessarily to the following considerations:

In general, no overt steps should be taken to discourage students from careers in science and engineering. As a matter of fact, the various factors such as the feedback effect of exaggerated accounts of the unemployment situation, changes in Federal support, and a possible anti-science-technology syndrome may well provide a degree of discouragement towards careers in science that could lead to renewed shortages during the second half of the decade and beyond. As mentioned previously, an NSF survey carried out in the Fall of 1970, covering essentially all doctorate-granting departments, shows that first-year, full-time science and engineering graduate enrollment decreased by 2½ percent. In contrast, overall first-year full-time graduate enrollment in all fields was shown by another survey to increase by more than 4 percent.

While steering students away from science careers does not seem to be in order, I strongly believe that students contemplating careers in science and engineering should be carefully counseled about the outlook, especially with respect to the degree of opportunity in specific types of science activities. It is precisely at this point, the time a student chooses a major area of study, that one should concentrate on changing false value concepts.

The probable changes in the nature of future employment opportunities also clearly point toward a re-examination by universities and colleges of their curricula and degree structures. Institutions of higher education must make sure that they provide a variety of educational options which prepare future scientists and engineers for different types of careers. Thus, the educational programs of the 70's should include more diverse and interdisciplinary as well as problem-oriented undergraduate courses. On the graduate level, work-study programs and internships should be considered to provide students with the opoprtunity to obtain first-hand experience with different types of science and engineering activities. Doctor of Art programs for two- and four-year college teachers and practitioner degree programs for those planning careers involving non-R. & D. activities, should become more readily available. An example of a practitioner degree would be that of the socio-engineer who intends to concentrate his activities on urban problems with a high technology content. Clearly, this requires training beyond the baccalaureate degree, with primary expertise in engineering but also a very heavy concentration in the social sciences.

Such new degree programs should, of course, be offered in addition to the traditional Ph.D. curricula for those who want to and can be accommodated in research and/or university careers. On the basis of experience, most of us know that modern technology is based on a broad foundation of fundamental knowledge. Studies, such as the one published by the National Science Foundation under the acronym TRACES, have provided systematic analytical evidence of this symbiotic relationship. A curtailment of our quest for new knowledge, produced by Ph.D.'s, would undoubtedly produce dire national consequences evident only in the ensuing decades.

I realize that some of the suggested changes which I have mentioned and which are already beginning to appear, albeit at a very slow rate, will require institutional innovation at the university, college and governmental level. However, it is a vital necessity that our institutions of higher education respond positively to the new challenges posed by our present times. Should they fail to do so, society will not wait and, at least, the research required to deal with some of the very urgent, current problems will be carried out at other types of institutions. I would consider this to be a national disaster with long-term implications not only for academic institutions but also for the country as a whole.

Of course, the challenge of improving the preparation of our future scientific and engineering manpower for a variety of careers rests not solely within the confines of academia. I have mentioned the need for flexibility in students, faculty, institutions, and curricula, as well as the need for actual work experience and contacts as part of the educational program. To develop all of these will require overt, active cooperation and assistance from government and industry alike. The non-academic sectors should try to make their scientists and engineers available to universities and colleges for advice, counseling and teaching. They should open their doors for students to obtain first-hand work experience and they should take overt steps to establish much closer working arrangements with academic institutions. All of these actions are necessary to produce better exchanges of experiences, concepts and approaches between all types of institutions that depend so heavily on highly-trained scientific and engineering manpower. This dependence alone, to say nothing of the concern for national welfare, should prove to be a sufficient incentive to strengthen government, industry and university interactions.

While I have looked mainly at the 70's, a word of caution must be injected about supply-demand relationships in the years after 1980. Since the number of births in the U.S. has decreased throughout the 1962-1968 period, it seems likely that higher education enrollments will reflect a decrease in the 18- to 26-year old population starting by 1980. This will have two effects. In the first place, at least on a relative basis and possibly on an absolute one, we will be producing fewer scientists and engineers during the 80's. Furthermore, employment opportunities in two- and four-year colleges as well as in universities also will reflect this decrease in the college-age population. Thus, academic, governmental and industrial planners should be well aware of this inevitable change. This point is well highlighted in the studies of Brode and Cartter which I have mentioned.

With all the problems caused by the various transitional aspects of the 70's, I still would like to conclude on an optimistic note: American science and technology and American science education are still the finest in the world. Boundless opportunities do exist and will continue to exist for scientists and engineers to add to our knowledge of the universe and to make this a better world in which to live. My only admonition is to have us pay heed to the rapid changes of our times and to have us respond to them in a flexible, innovative fashion which has been so characteristic of the United States and which has led us in the past to a level of personal, scientific and technical well-being that is still the envy of the world.

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