Title
A. C. S. OPERATION INTERFACE ADDRESS.

Author
Brewer, Leo.

Publication Date
1970-08-01

Presented at American Chemical Society-
Operation Interface 1970 Meeting, held at
the University of California, Berkeley,
and IMRD, LRL, August 3-4, 1970

A. C. S. OPERATION INTERFACE ADDRESS

Leo Brewer

August 1970

AEC Contract No. W-7405-eng-48

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

2

DISCLAIMER

A. C. S. Operation Interface Address*

Leo Brewer

Inorganic Materials Research Division, Lawrence Radiation Laboratory
Department of Chemistry, University of California
Berkeley, California

Dr. Barney, the organizing chairman of this meeting thought that the Universities and Colleges might take a beating at this session; so he placed me at this point in the program to serve as a sort of hatchet-man to defend the schools. We are hoping to have some lively discussions when we break up into smaller groups this afternoon and I will try to present some of the issues rather sharply even to the extent of setting up straw men.

I would like to discuss the questions of quality and quantity of students working for the Ph. D. degree. I have watched the students coming through at Berkeley for the past thirty years and I can note no significant change in the quality of students over that period. I think that we are drawing the line at which students are allowed to advance to their degree at a proper level judging by the productive scientific careers of those who just barely made the grade. We hear many complaints about the type of training that students receive. I have heard industrial

*Presented at the American Chemical Society - Operation Interface 1970 Meeting, held at University of California, Berkeley, and IMRD, Lawrence Radiation Laboratory, August 3-4, 1970

recruiters complain because our students weren't training for the specific techniques or instrumentation used by their particular industries. One recruiter complained that one of the men he had interviewed admitted that he had never done any gas chromatography. I don't think that the schools should provide such specific training. The principal objective of the work toward the Ph. D. degree is to teach the student how to learn on his own. He may work in a very narrow field to demonstrate in a reasonable period of time his ability to do independent work, but his Ph. D. degree should be a symbol that he is capable of learning on his own in a wide range of fields. At the University of California, this idea, that a Ph. D. has demonstrated his ability to learn in any field, is held so strongly that a second Ph. D. will not be given. Recently, a Ph. D. in physics who wished to obtain a second Ph. D. in psychology was refused on the grounds that even in such far-removed fields, a second Ph. D. would be redundant.

What do we expect of a Ph. D. and should the training be different for a student who might work in industry compared to one who might become a teacher? I would maintain that there should be no difference. Chemists as a group are expected to know what will happen when any conceivable mixtures of elements are put together under any specified conditions and to know what the properties of the resulting materials would be. At either the academic or industrial level, we can answer these sorts of questions efficiently only from a fundamental understanding of factors that control the properties of materials. The training of a Ph. D. thus serves two functions; it teaches the student how to learn on his own and the research carried out for the thesis adds to our fundamental understanding. I maintain that it is no longer possible for industrial research and development to be carried out by thumbing through handbooks or by trial and error experiments. The requirements in most industries today are so novel that conventional materials are not satisfactory. The number of combinations of elements that might be considered as a source of materials are astronomical. To meet a specific design requirement, one must have a basic enough understanding of materials to be able to predict the general classes of substances that might meet the design specifications. Once the problem has been reduced to the consideration of a relatively small group of materials, then one can afford to use trial and error procedures. The understanding for meeting such design requirements is the same as that needed for academic research. A fresh Ph. D. may never have heard of any of the materials that might be needed to solve the design problem; in fact, some of the required materials may not have been discovered yet. A properly trained Ph. D. should know how to use the literature to learn the required background on his own. He would have learned to use inductive logic to set up models to represent the systems of interest and to apply deductive appraisals. He would have had problem-solving experience. These procedures are universally applicable. Although they may have been learned through applications in one narrow field, the procedures can be transferred to any other field. He does not need to know how to push the buttons on a particular piece of equipment of interest to a particular company. That sort of training is easily accomplished on the job.

I recently heard an industrial research manager explain the operation of an industrial laboratory in the following way. He drew a funnel with the section near the wide mouth representing the primary research that feeds the ideas into the organization that ultimately lead to the products coming out at the narrow end. Since primary research is cheap, the company can afford a large number of projects. The next step would be a pilot-plant testing of the idea or material which is more expensive and thus can be maintained for only a few of the initial ideas. At each step up to the large scale manufacture of the final product, the cost rises and the number of projects that can be carried on must be reduced. In these days of declining industrial profits, many companies are reducing their support of their primary research. I would propose that this is the time for expansion of their research since the chances of profitable products coming out of the narrow end of the funnel is increased by increase of the wide end of the funnel. It is very important for the vivability of any research organization that there be a continuous infusion of young blood and new ideas. Organizations that continue the policy of retrenchment in hiring for very long may find that they have destroyed their research and development capability. Much alarm has been expressed about the so-called oversupply of Ph. D.'s at the moment. My concern is with the shortage of trained people. I would agree with Dr. Bickford that job opportunities for chemists will double over the next five to seven years, but I do not think that it will be possible to train enough people to fill these job opportunities. Science and technology in general have been growing at an exponential rate that is considerably higher than the rate of population growth. This has been achieved through importation of technically trained people from abroad and by the increase in the proportion of our population that received advanced training. In California we have reached the point where well over 70% of high school graduates continue with some type of advanced training. We can no longer increase the number trained by large factors. It is not likely that the fraction that choose scientific careers will increase; all indications point to a decrease. Thus the increase of technically trained personnel cannot grow in the future more rapidly than the population growth. This limitation will surely reduce the rate of technological growth unless we can, somehow, increase steadily the efficiency of our technically trained personnel. In any case, the long term projections indicate a shortage of scientists and engineers that will throttle technological expansion.

The present temporary shortage of positions gives us a good test of our educational system. We had a previous test of the education of geologists over ten years ago when the A. E. C. decided it had enough uranium reserves and, by chance at the same time, the major oil companies decided to curtail oil explorations. A large fraction of the geologists suddenly found themselves out of work. Those that had received a broad basic scientific training were able to switch to other scientific positions; the ones that had been narrowly trained had to take non-technical positions. I think that most of our Ph. D. chemists have been trained broadly enough so that they can switch to a variety of areas in chemistry or they can make the jump to the biological sciences or to materials fields such as metallurgy, ceramics, etc. An important part of their training should be the emphasis upon the unexpected directions in which science may turn and the need to prepare themselves with a broad base to allow them to take advantage of the new directions. I can cite my last three Ph. D. students as examples. Paul Cunningham who measured nano-second lifetimes of optical radiative transitions is now working on the alkali metal-sulfur batteries. Paul Wengert who studied the stability of intermetallic compounds is now working on gases in glasses. Baldwin King who was trapping high temperature vapors in rare gas matrices at liquid hydrogen is now synthesizing new compounds from aromatic and silicon compounds. As I emphasized earlier, we expect our Ph. D.'s to make switches like that. Their thesis work demonstrated that they had learned how to learn and this ability could be applied to any scientific field. It is often suggested by industrial people that academic research should be geared to industrial problems so that our Ph. D.'s would be better prepared to tackle industrial problems. I think that this would be a terrible mistake.

We would be preparing our students to solve the industrial problems of the last decade instead of preparing them to solve the problems of the next decade. When one looks back at the progress of science and technology in past decades, it is clear that no one could have anticipated the new developments. Our students must be trained broadly enough to be able to change their directions flexibly as new opportunities appear. The academic institutions should strongly resist pressure from industry that is designed to direct the training of students along directions of current industrial interest. In these days of attack upon the Universities and Colleges from all directions, industry appears to be increasing its effort to direct the activities in academic institutions.

In these times of a temporary surplus of scientists, industrial management may consider the academic institutions to be an inexhaustible supply of both technical personnel and ideas, but like the goose that laid golden eggs, the academic institutions can be debilitated to the point of destroying their productivity. Academic institutions are not constituted to defend themselves against the mounting social and political attacks and industrial management has a responsibility to defend the schools that provide their golden eggs. For example, legislators usually are not aware of the vital dependence of industry upon the schools. When a legislative attack is being mounted against the schools, I would contend that the industrial lobbyists, who have ready access to the legislators, should be defending the schools and pointing out that the vitality of industrial development depends strongly, in the long run, upon the vitality of the Universities and Colleges.

The maintenance of the vitality of the educational system is important not only for industry; the continued existence of the human race may depend upon the vitality of our academic institutions. Society faces very serious technological problems of a considerably different character and different order of magnitude than the conventional problems of the past decades. It will take great political and social ingenuity to solve these problems, but their solutions are quite impossible if not based upon sound scientific and technological developments by technically trained people who are not fettered by the conventional procedures of the past decades.

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720