Importance of Ecology in the Training of Engineers

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I SHALL BEGIN WITH THE STATEMENT OF several propositions:

(1) Engineers and those who direct their activities now play a great, if not a preponderant, part in shaping the daily activities and thus the general pattern of American life.

(2) The fundamental and inescapable basis of human culture lies in its relation to the means of subsistence—the maintenance of soil, the conservation of water through agriculture and the related arts which apply biology.

(3) Engineering activities profoundly affect the material and energy cycle upon which civilization rests.

(4) Engineering students, along with those preparing for the practice of medicine, rank among the groups having the highest intelligence in American colleges and universities.

(5) Current and accepted practice in the training of engineers affords practically no opportunity to learn the fundamentals of biological science.

The means of subsistence and much of the essential energy and raw materials needed by the people of the United States depend upon the order and balance of the landscape. The fixation of carbon by green plants, which is the fundamental process in living nature, depends upon the maintenance and improvement of soil and the conservation of moisture for its efficiency. Technological activities which interfere with these processes run counter to the general welfare in that respect, introducing factors which are just as essential to good engineering practice as a knowledge of dynamics, design, or materials.

The problem can be exemplified as follows:

Highway construction. This operation involves drainage, usually designed with but one end in view: to keep water from the crown of the highway and move it away as rapidly as possible. The aggregate area of highway appears to be about 1 per cent of the national area. If this meant a reduction of only 1 per cent in the moisture available for agriculture, it would not be serious. But our highway system drains much of the adjacent land and constitutes a rectilinear system of general drainage, supplanting the natural curvilinear system of stream tributaries.

This superposed drainage pattern has two serious consequences. It accelerates movement of water into main drainage channels in flood time and interferes with maintenance of ground-water level by removing water before it can soak in. Also, by speeding the movement of water in earth channels, it leads to roadside erosion and consequent lateral gullies into agricultural land. These problems are most serious on locally built and maintained roads—the so-called county laterals. In one group of counties studied, the average county road level had been lowered three feet in 40 years and was responsible, in large part, for an average of 10 gullies to the mile in adjacent farm land. The total mileage of such local roads is many times that of main highways.

Stream sanitation. Neglecting the amenities to which streams and ponds contribute, the potential food production from clean inland waters is about equal to that of good average farm land, acre for acre, and increases up to a limit with increase in depth. Millions of dollars are spent annually in the stocking of inland waters in the United States, but this money is largely wasted and an important food resource rendered useless by industrial waste and urban sewerage. While this tremendous and tangible loss can be attributed to social and economic faults, it actually stems from defective ideals of industrial and municipal engineering design. Such designs are not technically complete unless they reckon with the disposal of waste in a manner that will not produce economic loss and damage to other property, public or private. In the Miami River, in August 1946, over 200,000 fish were killed by the toxic wastes of one industrial plant, for example.

Stream control. This has as its primary objective the lessening or prevention of flood damage, but the conservation of water for public use and navigation is scarcely less important. Apart from increased use due to greater population density, the per capita requirements for water are steadily increasing with technological advances and improved living standards. The hydrology of a stream extends to the limits of its drainage basin, and fundamental hydraulics needs to reckon with the impact of raindrops as well as the phenomena of large volumes of water. The point of view with which the ecologist approaches water relations is as essential to stream control as the conventional approach of the engineer and must be incorporated into engineering techniques to make them effective. The fact that an ecological approach has been used in such projects as the Tennessee Valley Authority and the Muskingum Watershed Conservancy District is likely to cause overoptimism. One dam, built since 1935 at a cost of over $20,000,000, was completed without attention to ecological factors. In fact, the suggestion

Presentation before the Symposium on Applied Ecology of the Ecological Society of America, AAAS Boston Meeting, December 28, 1946.

that the valley be regarded as a unit and attention be given to soil and drainage conditions upstream was vigorously rejected. Within a few years after completion, the dam had intensified flood damage, and the reservoir behind it was silting rapidly, leading to a frantic demand for improved land use upstream. Sound engineering design would have reckoned with these hazards in the first place, in addition to those recognized by custom as engineering problems.

Turning now to the curricula in engineering schools, those of 10 leading institutions, with enrollments from 2,100 to 4,900, are of interest. In none of them does the generalized first-year course call for, or even allow, any biological instruction, nor is any provided for in any of the subsequent specialized years, with the exceptions to be noted. The normal courses in civil engineering usually include water supply and sewerage engineering, but for these the prerequisite is hydraulics only. In one school engineers may take forestry and conservation among their 15 hours of electives. The two other schools offering such courses appear to limit them to agricultural engineers, and even if they did not, the usual practice with electives for engineers is to confine them to strictly professional subjects. In three instances courses in soil mechanics are provided, but it appears from the descriptions that none of these goes beyond the promise of its title in giving an understanding of soil fundamentals. Thus, it is either difficult or impossible at present for civil engineering students to have contact with a field vitally related to their work. This is even more true of engineers, chemical, mechanical, and electrical, who will be expected to design industrial plants.

Two special fields of engineering involve biology explicitly. The first is agricultural engineering, the second in its fullest flowering is known as biological engineering. Agricultural engineers vary in training from civil engineers with courses in agronomy and animal husbandry (no basic biology and no ecology) to agricultural majors with sufficient engineering electives to qualify them. The latter may or may not have had ecological training—generally not. From observation I would say that much of the success of graduate agricultural engineers depends upon their boyhood experience with soil, water, growing crops, and domestic animals. They are at least aware of certain phases of reality which to the city-bred graduate engineer are a closed book.

Biological engineering, as exemplified in one of the 10 institutions, is slanted toward industrial production of biological materials and includes adequate training for certain types of biological research, fundamental in character but wholly remote from environmental studies—that is, ecology. From this high point it grades down to sanitary and water supply engineering which, as we have noted, is innocent of fundamental biological discipline.

In only one of the institutions under discussion is a course in ecology available, and then outside the pale of engineering education. In three of the schools, courses in conservation are offered to, and, it is to be hoped, elected by, engineers.

These matters concern the self-interest of the engineering profession no less than the interest of the public. In 1936–37 the head of an engineering school was greatly concerned because he could not place his graduates in civil engineering. Yet there was at that time an acute shortage of technicians to serve the numerous soil conservation districts then being organized. If these graduates had had the slightest knowledge of soil and vegetation, they would have been in demand. At his request a special course was organized in one of the biological departments of his university. One engineer attended the first meeting of this class—a graduate assistant who was sent over to learn the ropes, in full confidence that he could pass on any necessary information to young engineering students by sandwiching it in between really important matters. When the situation was brought before the director, he explained that required courses in engineering left no time for anything else, and that his school would lose its rating if he interfered with custom! In view of this, his original proposal was puzzling, to say the least.

Recently one of the engineering officials of a major American corporation, speaking before the alumni council of an excellent technical school, said bluntly that from his experience he would rather have engineers trained in the liberal arts atmosphere of a small college, which he named, than the crack professionals from this technical school. He went on to say that the men with a liberal arts background were more resourceful, more flexible, and more imaginative in their approach, all of which more than compensated for their lack of specialized technical courses. It was his opinion that, with a proper foundation, these specialties could be picked up on the job. What had been lost through lack of broad training could not. In my observation, one of the things least likely to be acquired without some measure of formal training is a comprehension of broad biological principles.

The biological profession is not without responsibility for the situation which has been described. In its general courses it has ridden evolution to death, emphasizing technicalities of structure and function while neglecting the great framework of life and environment which gives these technicalities their significance. Many such courses are geared frankly to the supposed needs of future professional biologists. They would ill serve the needs of engineers who took them. And, assuming that ecology is offered (which is not yet the case in many institutions of higher learning), these formalized courses in beginning biology constitute a *cheval-de-frise* that must be encountered first.

Biological science has much to offer that is of extreme importance to the engineer and to the future layman as well. I suspect that such material is of no less importance as an introduction to the professional study of biology. It is perfectly possible to teach a respectable introductory course so that no future engineer who takes it will thereafter be blind to the broad biological consequences of his professional work. But until such a reform in emphasis and arrangement comes from our side of the fence we are in a poor position to urge that the fence be let down.

At a higher level of instruction, it will be a great contribution if we can overhaul our courses in ecology, building them squarely into the structure of the other natural sciences. The possibility of this was suggested long ago by Henderson in his *Fitness of the environment*. It has been carried beyond the point of suggestion by both Jenny and Nikiforoff in their studies of soil energetics and has been considered by Transeau in relation to vegetation. Unquestionably, much more research is needed on such problems as the energy patterns of plant communities and drainage systems. But the basic means exist for organizing what we know so that it will carry its influence down to the elementary level in biology. Once this is done, that influence may extend across boundaries of knowledge to command the professional respect and serve the needs of that magnificently disciplined group of our colleagues, the engineers.

Meanwhile there is the possibility that those who train engineers may take some initiative in the matter. It is encouraging to note that The Ohio State University, along with several other institutions, is inaugurating an optional five-year engineering course in the hope that it will result in broader training. I do not envy the dean who attempts seriously to liberalize the present tight curricula. It will take courage to follow the course of reform in medical schools; it will take even more to avoid the pitfalls which have at times defeated the intent of premedical liberal education. I predict, however, that the first good engineering school to grapple boldly with the problem will acquire such prestige that other institutions will hasten to follow its example. It is generally true that the schools with the highest standards have the longest and best waiting list.

Shift of Employment Among Younger Scientists

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SCIENTIFIC PERSONNEL HAS PROBABLY never experienced the situation now existing with respect to demand. The unprecedented enrollment in institutions of higher education and the great expansion in scientific work generally have resulted in extraordinary recruitment efforts by employers. Evidence of unusual shifting of employment by scientists has been apparent. In particular, the less fortunately situated higher educational institutions have complained of the difficulty of recruiting and maintaining faculties in the sciences. The implications of rapid shifting are clear enough to require no elaboration. The smaller institutions do train a very large proportion of the higher-education population. Should much shifting occur, it would seem likely that properly qualified instructors would become unavailable for a significantly large part of the students in colleges and universities.

To secure some measure of this trend, the Office of Scientific Personnel of the National Research Council has polled a sample of those receiving doctoral degrees in the sciences in the years 1936–45, inclusive. The survey was confined to 13 disciplines in which the maximum competition for personnel among educational institutions was expected. About 10 per cent of the total number was selected as a sample, with slightly higher numbers in some disciplines. The survey was confined to the years stated, since the future of the sciences lies largely in the hands of the younger men. This does not mean that older scientists are not shifting. But especial importance seems to attach to the distribution of those who must be the leaders of science in the near future. Although replies are arriving daily, the present study includes only approximately the first two-thirds to reply. A rough check of perhaps 200 later replies does not alter the results significantly.

One interesting fact is that almost 10 per cent of the questionnaires were returned without forwarding addresses. Since the original addresses were in practically all cases relatively recent, the implication is that most of these individuals had shifted employment. Thus, figures on shifts in employment given below must be corrected upwards by a figure of 9 per cent or less, depending on the interpretation of the lack of proper address.

Table 1 shows the shifting occurring within the past 12 months among the first 975 scientists replying to the questionnaire. It will be seen that 248, or 25.4 per cent, have actually changed employment. The greatest shifting is within education. Here, 92, or about 10 per cent, of the younger scientists have changed jobs. Most of these have found more favorable employment in some other educational institution, although 26 have left the field of education. The Government has lost about 80 scientists, most of these going, presumably, to the universities and colleges. Much of this probably occurred