AN ENVIRONMENTAL FOCUS FOR ENGINEERING EDUCATION*

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For a number of reasons, historical and perceptual, educators are in a period of awakened concern for the world around us and for our relationships with it. Like the proverbial oversize suit that we would "grow into," the world is getting tight in spots and we can forsee its getting tighter. Unlike a suit of clothes, we cannot buy another world; we will have to live within what is available. The pressure upon educational institutions is indirectly through the needs implied by our environmental pinch and directly through the demands of students, the faculty, and even the educational process for relevance.

Many have written and spoken on the importance of environmental problems and desirability of universities giving attention to them. An important question is whether a university or one of its subdivisions will take up environmental problems in the same manner as it has approached others or whether a new pattern of approach should be used. As will be developed in the following discussion, my view is that a different approach is called for, consistent with a concern for both our environmental problem and the effectiveness of engineering education.

A starting point for this discussion might be to ask the question: "What would be the purpose and nature of an engineering school oriented toward problems of the environment?" In answering the question we should consider what environmental orientation means, what engineering education requires, and how the two can be joined.

Man and Environment

The meaning of environment in its broadest construction is all factors external to an organism which can have an influence upon it. Given that our concern is with man, what are the factors which comprise his environment? Commonly we think of the physical necessities — air and water — but we should also include food. On the negative side are hostile agents such as weather, radiation, disease producing organisms, pollutants, and predatory animals, including man. Acting through cognitive processes are the organizational or social influences and the singular or aesthetic factors. One can see that to understand man's environment is equivalent to understanding man; what he is and what he responds to.

There is a secondary group of factors which are the mechanisms of our responses to environmental demands and which in themselves become part of our environment. We need shelter to protect us from the weather and to provide suitable facilities for preparing and consuming food, for building devices, for resting, for dealing with disease, and many other functions. These shelters and work places — homes, offices, factories, stores — become forces which to some extent shape our patterns of activity and thought. In deed, they usually are more immediate and continuous elements of the perceivable environment than the forces of nature.

Transportation is vital to every phase of life, enabling the movement of materials and people

*Presented at ASEE Meeting in Los Angeles, June 18, 1968.

and becoming a part of life's quality and scheme. Equally important and obvious are the roles of power and communication. At the base of all these factors are the natural resources whose magnitude is the ultimate limit of our capacity for sustaining life.

These factors are provided or controlled either by natural processes or by man's deliberate effort. Man's response to them in the past has been largely adaptive. He would seek a hospitable area for optimizing all needs or he would avoid the inhospitable. A measure of our progress has been our growing ability to change or destroy the inhospitable and to create hospitable factors — the ability to control our environment.

Orientation

A university which concerned itself with the environment would be characterized more by an orientation than by a catalog of its detailed activities. There is no such (sensible) thing as environmental mathematics, or literature, or history, or chemistry, or transport phenomena. What can be special are the use to which basic knowledge and methods can be put, and the motivation of learning and inquiry.

The general outlook of an environmentally oriented school would be directed toward our ability to live within the capabilities and resources of the earth. More specifically, it would be addressed to answering the broad questions:

1. Who and how many are we? What kind of people will populate the world, how will they be distributed, and in what numbers at various times in the future?

2. What are and will be our objectives? How will we accomplish them?

3. What do and will we need?

Consistent with the ramifying character of environmental considerations, the people working in this area must develop a personal sense of the contributions all disciplines can make. Management implies a multi-professional approach because of the necessity for resource allocation. In order to decide how to use the limited resources one must understand all of the competing claims upon them and all of the possible routes to their satisfaction. The old dilemma of "guns or butter" summons up the picture of this type of decision situation.

To expect that individuals can be educated to handle all aspects of an environmental problem is naive. The best engineering design will

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be done by an engineer, economics by an economist, toxicology by a toxicologist, and so forth. Each of the professionals contributing to the solution of the problem must be in close touch with his professional colleagues and literature so that he may be expected to bring the best state of its practice to bear upon the problem. Yet he must be knowledgeable in all its aspects, probably to the point of being able to handle simple tasks in other disciplines, in order that he not overlook the need for assistance and possible interactions.

Another important element of the environmental orientation is the development of a sense of innovation; both of the need for change and the ability to accomplish it. An instant behind the question: "How does it work?" should be "How else can it be done?" It is difficult to state this as a unique characteristic of an environmental program — we would doubtless like to see it in any engineering education. Let us say that there is a greater need in the case where the present state of affairs is the result of a complex and non-intellectual evolution and where each man is very likely to be working alone rather than as a part of a technological hierarchy.

Rather than having his problems chosen and defined for him each person must possess an awareness of need. We might define this awareness as the ability to observe and speculate and to sense the opportunity or necessity for adaption. In that our reasoned approach to environmental management is at a primitive stage, we have no procedures and organization which relegate a bounded and fractional (small) role to each participant. It is still a wide-open, wild game and it calls for a perceptive entrepreneurial outlook and competence.

Method

A method for providing the special characteristics of an environmentally oriented school is as follows in outline:

- **Address the school to the question of our ability to live within the capabilities and resources of the earth.** This should be reflected in

all functions, education-research-service, by their becoming specially competent in environmental planning and management. Simultaneously, strengths in basic disciplines are to be developed so as to permit a range of opportunity for their application. In terms of engineering education this means that design and applied problems used in basic core courses as well as systems designs will be related to our environmental needs.

• **Provide the structure and functions for an interdisciplinary approach.** Curricula should stem from a common core which will provide a real understanding of all disciplines and, further, will enable a significant mobility of students into any discipline. This is both economical of course offerings and essential to the student's preparation for continuous education in the future in order to accommodate new knowledge. Applied interdisciplinary projects can reinforce and multiply the conceptual links which each student has with areas outside his major as well as strengthening his concept of and capability to apply it. By drawing these projects from the surrounding real community we can provide the relevance and motivation the students (and faculty) need.

• **Use the campus itself for research and demonstration.** Educate and inspire by setting an imaginative example. This should involve not only the organized research activities but the actual campus-community context in the course work and research of the Engineering School.

Requirements for Engineering Education

Let us now turn our attention to the question of the ingredients of a good engineering education. The main emphasis will be on the undergraduate program as is consistent with the conviction that engineering education does have unique properties which must be incorporated into the entire college education of an engineer. The essence of this uniqueness is a motivational factor more than a substantive one. Engineers are distinguished by a desire to create and to control some component of the real world. This requires patterns of attitude and thought which are best developed at an early age.

To do a good job of engineering education one has to:

1. Present the basic physical, chemical, mathematical, biological sciences so that the student understands most of the important phenomena and has enough of a base so that he can continue to learn by self education if necessary.
2. Teach the basic engineering approaches which embody useful methods for problem solving and teach a method of intellectual approach to problems.
3. Confront theoretical predictions with reality to illustrate the usefulness and limits of both the theoretical and empirical approaches and to give experience with a broad range of reality.
4. Provide course sequences in the social sciences and humanities which will give the student knowledge of the history and nature of man, a base for future self-education, and understanding of contemporary social, political, and economic systems sufficient to illuminate the relationships between man, technology, and the world and to enable his conception of useful programs.
5. Teach the student to solve problems, to design, to think, to make use of acquired knowledge, to generalize, to fill blanks with reasonable assumptions.
6. Teach the scientific method and logic.
7. Provide for continuing education.

The methodology used to achieve the above goals in engineering education will have to satisfy several constraints. Some of these constraints are that the program has to incorporate:

1. Real problems which may involve a variety of disciplines and may not have a single "best" solution—to teach problem solving, design, the "engineering approach," and to provide links between the separate courses and the total practice of engineering.
2. Satisfaction of the student's desire to be involved in basic problems of society.
3. A means for more effective teaching of social sciences and humanities.
4. Better undergraduate teaching.
5. More effective research and professional activities for staff and students.
6. Better continuing education.
7. Independence from the danger of obsolescence accompanying preoccupation with current industrial technology.

Riverside Program

The Engineering school at the University of California, Riverside, is being established with a primary orientation toward problems of the environment. While there is no previous history of engineering at the UCR campus, there are several related activities which can be capitalized upon. There are capabilities on campus in air pollution, physical and biological sciences, agriculture, social sciences, dry land research, water resources, geology, and fire laboratory research. The data base in these related research areas provide a common body of knowledge for instruction in applied environmental engineering problems.

Students will be prepared for careers in industry, business, government, and education. They should have the option of taking employ-

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ment at the Bachelor of Science level or continuing with graduate school. They must, therefore, be employable (identifiable) in the present context where designated degrees are important and also be grounded in a primary professional discipline which is of enduring validity (and utility).

There will be three teaching divisions which will provide the basis for future growth and for present professional identification. While there will be a great deal of transference possible among divisions, they will each be distinguished by a strong orientation. They are:

Physical Division — dealing with mechanisms, structures, power, physical processes, and physical properties of materials.

Chemical and Biological Division — involving chemical and biological systems, properties, and processes.

Information and Computation Division — covering information properties, processing, and systems — including applied mathematics.

In addition to the three curricular core divisions there will be an **Advanced Projects Division** which will coordinate research, professional activities, continuing education, and various liaison relationships. This division will provide the mechanism for an optimization of the teaching-research combination by a redistribution in time of the available effort for each. Faculty assignments will be arranged so that the teaching and research periods will each be more intensive and effective. It is envisioned that faculty will devote nearly full time every third year to research or professional activities administered through the Advanced Project Division.

The teaching and research organizational structures will be separate and not identical. Research groupings will be consistent with specific objectives and will form, disperse, and reform as needs dictate. Teaching divisions will be permanent units, subject to future modification in the light of experience, and the faculty during their period of assignment to the division will be responsible and accountable for teaching. Division heads will be concerned with either teaching or research and professional activities and with coordination among the divisions. Thus the organization of the school is consistent with the concept of function wherein the engineer applies basic tools which have a relatively long life to special problems which are generally transient.

The major curricular challenge in engineering education is in the undergraduate level, graduate programs being largely tailor-made for the individual student. The UCR undergraduate curriculum is based on a very strong common core and is not organized around the traditional branches of engineering. This arrangement offers greater flexibility both for the student in choosing a curriculum to suit his interests and for the School in making modifications to meet changing demands. An outline of the curricular patterns is given below. In this system a student could elect a divisionally designated BS degree, a professionally designated degree (from those offered to meet sufficient demand), or an undesignated degree. A few courses required to augment a divisional curriculum enough to form a designated degree (such as Mechanical Engineering out of the Physical Core) would represent a small investment and could readily be added or deleted from the Engineering School offerings.

The undergraduate educational elements are listed below:

- An environmental orientation is effected largely through design and applied problems in the following areas: air, water, food, shelter, transportation, natural resources, community systems, social interactions, and long range planning and management. These enter at all levels of the undergraduate program.
- All students take a General Core which accounts for 55% of the undergraduate credits. Subject areas are: Mathematics, Physics, Chemistry, Biology, Earth Science, Social Sciences, Humanities, and Economics.
- All students take an Engineering Core which accounts for 20% of the credits and includes: Mechanics, Transport Phenomena, Thermodynamics, Dynamic Systems, Materials, Systems Design and Optimization.
- Students may elect a Divisional Core or an undesignated program which accounts for the remaining 25% of the undergraduate credits. When there is sufficient demand there may also be designated degree options within the Divisions of utilizing perhaps one-third of the Divisional Core credits. Subject matter will be:

1. Chemical and Biological Division Core — Chemistry, Biology and Chemical and Biological Systems.
2. Physical Division Core — Mathematics, Physics, and Mechanical Systems.
3. Information and Computation Division Core — Mathematics, Computation, and Systems Analysis.

Air Pollution

One of the difficult environmental problems facing us is air pollution and we can gain insight into the role any environmental problem may play in education by reviewing some recent experiences with air pollution as an educational focus. The following section is drawn from the author's experience in establishing an interdisciplinary air pollution training program at Pennsylvania State University. Let us first review the nature of the air pollution problem and then the specific pedagogical device — the focal project.

In their beginning and in their significance air pollution problems are sociological (political) problems; they involve interrelationships between individuals and groups in society. While their phenomenological substance presents questions in science and engineering, their meaning to society is in terms of the various planes of man's life and thought. As individuals we react to physiological factors ranging from subtle influence to gross insult and to psychological (or aesthetic) factors ranging between comparable limits. In groups of all sizes from neighborhood association to national and international bodies we work to recognize, identify, understand, and control environmental factors. When decisions are needed the plane of economics serves as one of our principal bases for evaluation of alternative courses of action. **In general we can see that as a social-political problem air pollution has much in common with the multitude of questions that face the community.**

To consider the phenomenon itself, we may use the simple picture of the air pollution as a chain of "source-transport-effect." To understand air pollution we need knowledge of all three links of the chain but we note that transport and effect follow inevitably (offer no opportunity for control) from the fact of emission by a source. Control must therefore be upon the source and is in its specific nature an engineering problem. The kind and degree of control required depend on cause-effect relationships which are established through study of atmospheric dispersion, reactions during the dispersion period, and effect on man, animals, vegetation, and materials.

Changes in manufacturing processes, fuel availability, technology, population concentration, transportation, etc., will influence the specifics of air pollution. We can expect new problems to develop, some of the old ones to disappear and others of the old ones to grow. It is clear that the field of air pollution is not only broad but is also reflective of the dynamics of society. Significant progress on the problems of air pollution will require the depth of competence of professionals of many kinds who can turn their attention to new problems as they arise.

Focal Project

Teaching interdisciplinary subject matter to a multi-disciplinary group is one of the large unsolved problems in university education. We are in general not set up structurally or philosophically to handle such problems. They are not neatly organized, capable of closed definition or final correct solution; they are design problems. They require the application of all sorts of knowledge and it is nearly impossible to set prerequisite requirements which can be met by all of the mixed group of students who must represent the needed spectrum of skills. Professors who insist on highly organized courses requiring several stages of prerequisite preparation are likely to feel that interdisciplinary courses are not graduate level or even upper division undergraduate level.

It is enigmatic that a problem which is one of the very difficult ones for society is not considered difficult enough to be worthy of the attention of regular courses in our universities. We need a way of dealing with real problems and still do whatever it is that universities feel is a compulsive expression of their scholarly character. One approach is the focal project described here.

The focal problem was a single problem which received the attention of the class for a period of preferably one year. This sequence related to air pollution in the community and the individual problems were the study of the total situation in a city. Seminars, applied problems, field trips, and some research were to a large extent referred to the focal problem. Staff members and students were assigned to study and define the various (scientific, political, sociological, economic, engineering, public information, health, plant damage) aspects of the problems. They prepared and presented the study plan and source material for the seminar and for student projects. People representing industry, control agencies, municipal government, citizens' groups, news media and others were involved in the study and were brought in to address the seminar.

As a pedogogical device this provides the student with a familiar ideological framework to which he can relate new ideas. Likewise it provides people from different disciplines with a common reference structure and a secure starting point for the development of mutual understanding. This sequence supplements thesis research and will ensure a breadth of coverage of the field which does not result from work on specialized research.

Some of the term projects which were assigned to small groups of students are as follows:

1. Survey of effects of air pollution on the insect populations in Greater John Doe town.
2. Meteorology study. Apply standard diffusion equations to sources in the Greater John Doe town area and calculate pollution movement. Develop a proposed sampling grid for Greater John Doe town including location of samplers with respect to air flow, bridges, etc.; power supply, public places, etc.

Experience with the focal projects over a three-year period was encouraging and generally comparable to what we had encountered at Case Institute of Technology in chemical plant design and process development projects which were done in cooperation with industry.

Conclusion

Engineering education has been evolving through a series of stages in which it has related to rather specific activities which were the occupation of engineers. Its programs have been responsive to the needs of industrial, civil, or military activities until recent years when disappointments in various national enterprises have moved us to seek an independently directed method. An attempt to follow the example of the physical scientists by fixing the program on a basic research focus has not led to a useful mechanism for educating the undergraduate and has not provided any sense of direction for engineering.

The times now call for something different, for a display of initiative by engineers. Increasingly the technological source of our productivity and wealth, of power generation, of communication mechanisms, of the quality of life have placed a bewildering burden on society's decision makers. Political leadership has filled this role in the past but it is sporadic and becomes less accessible to the politician's competence as the issues become more technical. The posture of engineers have been responsive, "Ask me a technical question and 'll give you a technical answer." Who is going to ask the proper questions, recognize the emerging issues, pose the alternative possibilities, provide the visionary leadership?

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