regarded as absolutely true and right, together with a belief that where right answers are as yet unknown they are discoverable. Examples of such beliefs are: a balance sheet must add up, the cause and cure of cancer is discoverable. But administration is not like that and the answers aren't always right or wrong, or even discoverable. How much delegation should there be? To whom should one delegate? What kind of organisational structure is suitable at present and for a particular task? Answers to these questions will vary according to the particular task, situation, timing and personnel.

Administrators in health services today are, like all organisation men, thrust into a world of rapid change. They can no longer concentrate on running a hospital, in isolation from other health and social welfare services around them. To teach them slabs of Behavioural Science "facts" would, I think, merely continue the track on which they already stand far too firmly. So before I go in for any "content", I attempt to teach them to ask questions. This process shows them that the questions we ask are our instruments of perception, and ensures that the particular aspects of subject matter with which we deal are perceived by the students as relevant to their needs at this particular time. They have to formulate *answerable* questions, and this demonstrates that the form of a question, and the assumptions beneath it, determine the nature of the answer: a practical example of selective perception.

In finding answers to their questions, the dubious evidence for the existence of any facts becomes evident to the students. Once you start analysing suicide, attempted suicide, and suicide statistics it becomes fairly obvious that it is very hard to say that one country's (or group's) suicide patterns are higher than another's, let alone explain such patterns. The fallibility of statements and facts is perhaps the one fact students must learn.

Further, it seems to me very important that students should realise how constrained all our thoughts are by the language we use. We see our world as our language tells us to. Our students, many of whom have a medical background, tend to reify diseases and talk about "a disease" as if there is such an entity apart from the person who has the disease.

Both medical and administrative language are special ways of looking at the world; and those who use these languages miss important aspects which they need to see. Hence I spend some time on linguistics, though that may, by some people, be seen as falling outside my Behavioural Science territory. Yet the language of Behavioural Science too, obstructs—and clarifies, and should be regarded as part of the bias inherent in the subject.



So here I stand—with a home-brewed kind of course composed of problem-solving exercises, communications groups, role-playing on videotape, "stirring" so that students become uncomfortable and are forced to think again. Last year I tried another experiment—students in the Postgraduate Diploma, were given a number of books to read and review (each student read one book). Thus the whole class heard about a larger number of books than they could read themselves. And, in addition, there's the formal course-work as above including specific sections on medical sociology (for example, the infamous doctor-patient relationship, the process of becoming a patient, the place of health in society, the role of the health professions).

In looking critically at my teaching (I've been here for two years now) I ask: Where should my emphasis now lie? Is it more important to teach students to ask new questions, or should I concentrate on helping them to find a few answers? I too am in a state of ambiguity, and it will be interesting to see which direction the courses will take in 1974.

## ENGINEERING, TECHNOLOGY AND APPLIED SCIENCE—EXAMPLES OF LONG-ESTABLISHED INTERDISCIPLINARY COURSES

A. P. PROSSER*

IN some academic circles interdisciplinary courses are a novelty and an attraction for the individual who feels he has something new to say about human endeavour. However, there are other interdisciplinary courses and departments which have existed for so long that they are rarely recognised as such. Engineering, technology and (industrial) applied science are examples.[1] They have lost their novelty in this respect and, with a few exceptions, are less attractive to the radical innovator than was so 20 years ago.

For those who are not aware of the make-up of a typical undergraduate course of this type, the principal disciplines are science, engineering science and engineering. Definitions of each which will suffice for this symposium are that pure (physical) science is the discipline of extending and ordering knowledge of the physical world, engineering is concerned with the production of commodities and services for some part of the community and engineering

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[1] The three have much in common as far as this contribution is concerned and the use of one or other name in the text is arbitrary.

science encompasses both the application of the basic laws to oversimplified engineering systems and the semi-theoretical, semi-empirical knowledge of the more complex systems. As a discipline it has more of the characteristics of science than engineering. Thus, heat content and fluidity of liquids are parts of science, the mathematical models of simultaneous flow and heat transfer between fluids is engineering science and the design of a boiler for a power station is engineering (including disposal of the waste products!).

This type of course has been taught at the tertiary level for more than 100 years. In Australia, the Universities of Sydney and Melbourne were the first to offer degree courses in engineering in 1883, in response to requests from political and industrial leaders. The University of Sydney Calendars of that time contain time-tables and examinations which show that the first year of study was concerned with science and languages (the latter were dropped in 1890), the second year with science and subjects such as applied mechanics and dynamics which would be regarded as engineering science now, and only a small proportion of time was allocated to the practice of civil engineering or metallurgy, mainly in the final year. As might be imaged, the engineering courses grew out of existing science courses; at Sydney the Faculty of Science was established in 1882 with a Department of Engineering, and the Faculty of Engineering as such was not founded until 1920. This pattern of development is probably true of most of the early engineering courses.

One exception known to the author is the Imperial College of Science and Technology, which is now part of the University of London. The College developed, again as a result of efforts by people outside education, from three independent institutions founded between 1845 and 1878, each with the clear intention of giving instruction in the applied sciences (applied chemistry, agriculture, metallurgy, mining engineering, applied geology and the three main branches of engineering). Science was taught in those institutions as a service only until the 1890s.

The sequence of the student's studies initiating with science and progressing to engineering science and finally to engineering has remained to this day in the majority of universities. Variations have been achieved, sometimes in terms of the relative emphasis on the three disciplines. Other variations have been for the students to specialise at an early stage in one branch of applied science or to deliberately avoid such specialisation in order to become "an engineer". More recently the variations have been related to several interactions between applied science and the community, i.e. an



up-dated version of the intentions of the 19th century entrepreneurs. It is remarkable how the disciplines of science, engineering science and engineering have remained identifiable in spite of the time and effort devoted to numerous curriculum developments, many of which must have been intended to lower the boundaries if not eliminate them. For the benefit of those who teach engineering students it seems worthwhile to examine some of the common premises that have become established. Others who are interested in different interdisciplinary courses may identify analogous questions and wish to take advantage of previous experience.

One common premise is that pure science must come before engineering science with engineering last, i.e. the sequence of the three disciplines has been fixed. The only exception has been to bring forward a little of the engineering but not to the extent that the sequence is substantially changed. The reason—which is often stated explicitly but without supporting argument—is that one needs the basic knowledge of science before one can understand and solve the problems of engineering. The philosophy typified therein needs to be challenged.

The entrepreneurs and innovators of applied science have "understood" not how scientific principles have been logically integrated to create their new technology but how their technology satisfied a need (existent or latent) of the community, how it created something of greater apparent value than it consumed, etc. They have identified and solved those problems which are closely related to the need. Few engineering innovations have happened by exploiting basic knowledge in a logical fashion, although subsequent development may owe much to the understanding obtained from scientific study. Thus, it is the meaning of the phrase "to understand the problems" which should be debated when the sequence of disciplines is to be decided. The value of science in solving problems is beyond reasonable doubt but it does not follow logically that one should learn the technique to solve the problem before one identifies the problem.

A second challenge to the established sequence can be based on its effect on student attitudes. A few students, particularly the academically successful ones, come to regard engineering as an interesting application of scientific principles or that the solution of problems within firm constraints of time and cost is unsatisfying. Some of the recent curriculum developments are aimed to modify such attitudes because they are incompatible with the profession as it is.

In the century of engineering education, relevant knowledge has increased dramatically but the time available for the students to become qualified engineers has hardly changed. Thus, the most common topic of debate about a course has been which parts should be retained in a syllabus and which can be omitted. One solution was to have courses related to more specialised vocations, hence limiting the amount of relevant knowledge; the fashion has passed, partly because it proved expensive in terms of the staff-student ratio. The other extreme, to concentrate on generalisations, was also fashionable. A wide variety of phenomena in engineering systems can be "explained" by a combination of the laws of thermodynamics and kinetics of mass, momentum and energy transfer, i.e. by science and engineering science. This approach has often been accompanied by a reduction in the time devoted to the engineering discipline. The rationalisation is that if one understands the principles one's employer and professional colleagues can complete the education process by concentrating on the engineering discipline after graduation. If engineering was only a set of established procedures and practices, that could pass unchallenged, but it is also an attitude of mind, a way of responding to the community's needs and to the physical sciences. The rationalisation also fails to recognise that a difficulty of engineering is to examine a problem in its broad context and modify it so that one seeks the most valid solution. (The criteria change because validity is related to community expectations.) Another unrecognised aspect is the difficulty of analysing an unfamiliar problem to the point where it is evident which basic principles are relevant and how they will be integrated to yield a solution. It is debatable whether the opportune time *to start learning* the attitudes and skills to deal with those difficult aspects is after the award of a bachelor's degree.

Another challengeable assumption is that associated with the service course. As we have seen, from the beginning, most engineering students have learnt their pure science from pure scientists in an environment of pure science. The rationalisation for the service course is contained in the rhetorical question "Who better to teach chemistry than the chemists, and where does one find the chemists?" Imperial College had an unusual origin in that pure science was taught for a long time only as a service for the applied science courses. That concept has not been entirely lost: physics and chemistry are taught there by physicists and chemists on the staff of the engineering and technology departments; there are few service courses given by the physics and chemistry departments. The author has taught chemistry in both circumstances at that and other institutes and is in no doubt that the intra-departmental



course is superior for the needs of engineering students. However, it seems to be not often considered seriously elsewhere.

We all know that modern engineering is deeply involved with community expectations, ill-defined and mutually conflicting at present, and that it has sociological and psychological effects on those who work in it. Also, it is probably general knowledge that applied scientists operate in professional teams rather than as individuals. Thus, few dispute the need for the engineer to acquire the skills for dealing indirectly with large social groups and directly with other individuals. However, it is commonly argued that the disciplines of management and communication cannot be taught effectively until engineers have experienced the conditions in which their profession works. Before that experience, students can neither understand nor accept tuition in these disciplines. In the author's experience the attitude of students changes a great deal as a result of two or three periods of industrial experience during long vacations. Also, the present-day students are much more aware of and sympathetic to this aspect of their professional work than their predecessors of five years ago. It seems worthwhile to continue experimenting with these disciplines but to recognise that what failed a few years ago could be successful now.

The preceding discussion of some common features of applied science courses seems to point to an element of inconsistency. It is said that the disciplines of physical science must be understood before real engineering problems can be tackled, but real engineering problems must be encountered before the need for the social science disciplines is understood and accepted. Various groups and individuals teaching in the applied sciences are finding it profitable to treat the physical sciences in a comparable manner to the social sciences, i.e. the students acquire these disciplines only when they have recognised the need for them. These teachers are introducing realistic and complex problems at an early stage in order to encourage students to enquire into the physical and social sciences in an engineering context. This is being done in some high schools as well as universities. The author is not aware of a complete undergraduate course in applied science based on this philosophy, as exists for law and medicine, but the development has reached the point where the start of one somewhere is imminent.

Another interesting anomaly is that courses of engineering and technology with major contributions from the science discipline are common-place whereas science courses with major contributions from the engineering discipline are not as common. Sometimes the latter have not thrived through a lack of students compared with those in the traditional science and engineering courses.

In summary, the position after 100 years of interdisciplinary courses in applied science is that:

—the boundaries between the disciplines are as apparent as they were in the early courses;
—the boundaries are most evident in the service course, where the students go to different people in different places for parts of the course and there is often little evidence of meaningful dialogue between the different teachers;
—the sequence of presenting the disciplines is debatable but it has not changed substantially;
—as a consequence of the expansion of knowledge the engineering discipline was nearly lost from the curriculum, but the danger has probably passed;
—of the concomitant disciplines, there is no clearly apparent reason why the physical sciences should always precede the engineering discipline whereas the social sciences should always follow it.

The fact that these features of the courses have been retained for so long is not only evidence of no great change but also of no obvious need to change. Good students have been attracted to and stayed with the courses, and as graduates they have been well-accepted by the community, more so than some others. This example of development in an interdisciplinary course is, therefore, not a bad one to emulate, although some modifications may still be desirable to meet the expectations of different people under different circumstances.

## SLIPPERY BOUNDARIES OF LIPID RESEARCH

J. B. Polya*

POLITICAL, economic and academic planning are seldom necessary to bring about the birth of fruitful ideas, but the development of projects to an applied or applicable stage requires funds, services and opportunities to arouse interest among students. Those who can guarantee support are not necessarily able or willing to tolerate novelty. Practical considerations rather than professional broadmindedness permit a breakthrough here and there, but interest in interdisciplinary research is often stigmatised as "amateurish"; and the most important branches of knowledge are often handicapped by neglect.

As an example, lipid research is not entirely ignored but its literally vital importance to man is poorly recognised or misused. To justify this statement the theoretical and practical significance of lipids will be summarised; then we shall consider some streams of lipid research and comment on the training and prospects of future workers in this field.

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Lipids are in common parlance fats and oils, particularly those of natural origin, e.g., butter, olive oil, the fats distributed through meat or circulating with blood, constituents of egg yolk that may be extracted with appropriate solvents, etc., etc. Given suitable conditions, including eons of time, similar lipids turn into petroleum, the study of which seldom attracts the typical lipid chemist.

The economic importance of animal and vegetable oils and fats is beyond argument. Apart from dietary purposes many are sold for industrial conversion into soap, other detergents and starting materials for explosives (e.g., dynamite), cosmetic preparations, plastics and remedies. Large industrial concerns that process fats and oils are major employers of chemists with tertiary or sub-tertiary training. Of these Unilever deserves to be mentioned for its excellent illustrated educational booklets that introduce students to data, problems and methods of pure and applied lipid chemistry.

In comparison with this teaching effort of an admittedly not uninterested party, academic curricula (except in departments specialising in food or industrial chemistry) tend to ignore the chemistry of lipids except, perhaps, for less than one per cent of the teaching effort devoted to some technical methods of analysis. These remain remarkably useful after a century or so but are dull to learn or practise. Predictably technologists of the future will make more or possibly exclusive use of modern instrumental methods which are intellectually more stimulating.

If the importance of lipids were purely industrial it would be reasonable enough to leave problems of special training to concerns interested in acquiring skilled staff. However, lipids play a variety of star roles in the functioning of biological systems. Dietary lipids store and dispense energy, part of their molecules can be incorporated into sugars and proteins; they are used to store water and to provide physical effects such as lubrication and thermal insulation; part of the lipids ingested turns into dispersing agents that bring about the absorption of unchanged lipids from the intestine. Chemical elaboration by the living organism converts the more common lipids into traces of vitamins and hormones that regulate our health and much of our psychology. Next to water, the most important constituents of the brain are lipids which must be