Towards a Better Environment : The Role of the Scientist

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In the pre- "ecoflap" period it was already clear to many people that accelerating population increases, accelerating resource depletion and accelerating pollution of earth, air and water must inevitably lead to a global crisis. Post "ecoflap" there can be few people in the developed world who are unaware of the environmental disasters which have already occurred and are likely to occur with increasing frequency but there are still surprisingly few critically constructive attitudes to environmental problem solving and in fact there is little appreciation of the range of areas of study which should be regarded as environmental. Thus the term "environment" is commonly understood to refer to the larger features of the natural and man-made world whereas we should recognise that every detail of the environment adds to or detracts from its quality and in order to emphasise this point with special reference to the role of the designer, Bernard Aylward (1) has noted that literally – although minimally – a pencil placed on a table in a room alters the environment for those within that room. Once due cognizance of the wide range and wide scale of environmental problems has been given it becomes possible to appreciate the need for co-operation of people with expertise in science, technology, sociology, law and design for resolution of existing environmental problems and prevention of anticipated environmental crises (2). The success of such teams would clearly demand a capacity of the members to communicate clearly with one another and to appreciate the problems of making compatible the approaches of the traditionally trained scientific and non-scientific members of the team. As a simplification one might describe the approach of the former as the search for absolute answers by way of the observation – hypothesis – experimental test approach (the hypothetico-deductive approach) whereas the arts and social science expert will have been trained to recognise the rarity of absolutes and will be orientated towards making value judgements which accommodate shades of grey as well as the scientists black and whites. Since environmental problems – and in fact most real life problems – are "fuzzy" and open ended the team would need to develop the capacity to maximise the constructive suggestions to be gained from each team member's approach and to eliminate the potential disadvantage of each type of approach so that they may agree upon a balanced approach to a particular problem. The satisfactory completion of the decision-making process is of course, only the beginning of the resolution of the environmental problem and one of the major difficulties about the problem resolution is that the layman tends to see everything in black and white and to make rash and simplistic criticisms of decisions which affect his environment. If the decision making body ignores the criticism because it is uninformed a potentially explosive situation develops because the critic feels that his views have been ignored. Hence, as Bernard Aylward observes, with the increasing complexity of society, the gap between governors and governed increases also and the communication link of informed criticism must be strengthened. Clearly these musings imply that not only is a special approach required for the "environmental education" of the decision makers but also for lay people in general. In a related context John Eggleston (3) has noted that a satisfactory design education for all children is essential if our increasingly crammed surroundings are not to be made aesthetically intolerabe for all because of ill-informed environmental planning by lay people (e.g. by what they plant and construct in their gardens).

Some years ago we began to work on the problem of constructing an honours degree programme which would provide an appropriate training for the scientifically orientated members of environmental problem solving teams and which would also equip its graduates for the equally important (for the reason indicated above) role of teaching in schools. Only if a completely satisfactory

and balanced environmental education is provided in schools can we hope to achieve the fully informed society which is essential for a satisfactory equilibrium between man and his environment to be achieved. Our planning of the new degree (the first intake of students was in September 1974) took into account that the graduates who we sought to produce must have a broad-based scientific education which would permit a balanced, scientifically appropriate resolution of the environmental problems which he faced. However we recognised that the provision of a purely scientific education would be quite inadequate since the graduate must recognise that there are severe limitations to purely scientific solutions. Often, the optimal scientific solution to a problem is totally unacceptable because it is economically absurd or sociologically intolerable. Hence our students have a training in the principles of economics and of man's interaction with society in addition to the purely scientific elements of the programme so that they will have sufficient knowledge to avoid any tendency to suggest scientific solutions which are inappropriate to real situations and so that they can, when necessary, readily develop a dialogue with the expert economists and sociologists in the environmental team. In order to achieve our objectives we provide the students with a sound foundation of biology, chemistry, physics, mathematics, statistics, computing and economics upon which is built a study of the environment and a consideration of the ways in which man may control his environmental impact. The course is taught in such a way as to stress the inter-relationships between physical, chemical and biological factors that make up the environment and to reveal the importance of economic and "social" factors in determining man's effect on the environment.

In some ways the preceding paragraph might appear to be summarisable as a confession that we proposed to re-introduce the old fashioned general science degree slightly updated by the addition of a flavouring of economics and sociology. This was not, of course, our view since we recognised that to a large extent the fall from grace of the (in many ways educationally worthwhile) general science degree was a consequence of the fact that little attempt was made to integrate material from the named "parent" disciplines (biology, chemistry and physics) into a coherent whole. In our presentation we have "married" physics and chemistry into a natural union called physical science and so the first two years of the course provide the student with a broad basis of knowledge of biology, physical science, mathematics, computing, statistics and economics in which coherence and integration are achieved by constant cross reference to the overall environmental theme of the degree.

The course is constructed as a "routed modular" programme. In other words the material is presented in discreet portions of syllabus material (90 hour modules) representing defined subject areas but the modules usually have other modules which are pre-requisites for them and are themselves pre-requisites for later modules. Thus our modules can only be taken at one particular point in the course and are not freely inter-changeable in the way that modules in several of the very broad degree schemes (e.g. City of London Polytechnic's scheme) are. Our structure was chosen because the alternative "flexible" modular system necessitates a considerable overlap of subject matter between modules and severely limits the possibilities of integration of material from separate modules. This would be completely contrary to our major objective of achieving coherence and ready cross reference not only between each of the traditionally distinct subject areas and the environmental theme but also between the subject areas in their own right.

In figure 1 I have indicated the chronological relationships between modules and some of the areas of cross reference and

"dependence". As can be seen each of the three years of the full-time course is divided into two semesters. In each semester there are four 90 hour modules made up of lectures, tutorials, practical classes and/or allocated time. The proportions vary according to the type of module being taught.

As can be seen from figure 1 the "compulsory core" of the course has been designed so that there are a number of developmental "threads" which cross relate to each other and to the environmental theme and which ultimately are drawn together in the third year Environmental Studies modules of which I shall provide more details later. The compulsory core modules also provide the basic knowledge pre-requisites for a student-selected group of modules in the final semester of the course. Each student selects three optional modules from a list of ten which are offered. The choices will reflect the students special interests but must form a logical grouping which will permit specialisation in either ecology or toxicology or environmental economics. These student-selected end points of the degree will ensure that there is a spread of expertise among the graduates. The inclusion of toxicology as a specialist grouping in an Environmental Science degree has been regarded as novel but seems a logical recognition of the fact that pollutants are of concern because they cause metabolic disorders in plants and/or animals and, of course, toxicology is a study of how and why such damage occurs.

In summary, the material in the degree is brought to an integrated environmental focus by the third year Environmental Studies modules (which adopt a systems analysis approach) and to a more specialised, student-selected focus, concentrating on Ecology, Toxicology or Environmental Economics. At this point it would be appropriate to consider in more detail the rationale of the various modules and of some of the module progressions. The material in the first year Biology modules has been selected to provide a basis for the Primary Ecology module and for the Metabolism (basic biochemistry) module. Primary Ecology provides the students with a basic understanding of the factors involved in the relationships of organisms with their environments which are pre-requisite for the Environmental measurement and Diagnosis module. In the latter module a physicist describes a range of environmental monitoring devices and explains their principles of operation and a mathematician explains the mathematical basis of good experimental design. This thread provides the ecological background for the Environmental Systems Analysis in the third year Environmental Studies modules and may also, of course provide the foundation studies for the specialised ecology modules in semester 6 and/or an independent ecology project in semester 5. In a similar fashion we may recognise that the basic bio-chemistry in the first year Biology modules is developed in the Semester 3 Metabolism module which in turn provides an essential foundation for the Microbiology and Microbial Genetics module. This thread provides essential background for the Environmental Systems Analysis and is also logically developed in the specialist Toxicology grouping by way of the Animal Physiology and Plant Developmental Biology modules.

The Physical science (integrated chemistry and physics) modules cross refer to the Biology modules in their provision of a basic understanding of molecules in general and, in particular, molecules of organic compounds which are the basic units of the bio-chemist. In addition the Physical Science modules provide an understanding of thermodynamics and of electronics which are crucial to certain aspects of the degree. There has been a tendency of chemists and physicists to teach thermodynamics in quite different ways so that it is not readily recognised as the same subject. In our programme the viewpoints have been necessarily unified and the laws have been presented as essential foundations of all scientific understanding

rather than as a rather nebulous (to many biologists) series of concepts. Thus our students are introduced to the second law (entropy – disorder – increases in the universe) with emphasis being placed on the fact that this law inevitably means that resolution of an environmental crisis at one point on the earth must inevitably create a bigger crisis elsewhere. Thus an environmental eyesore such as a slag-heap may be removed if a large amount of fuel is used – exacerbating the fuel resource crisis. The basic teaching in electronics in these modules lays a foundation for the students understanding of the Environmental Measurement and Diagnosis module which was mentioned earlier. Both the latter module and the Physical Science modules drawn heavily on the foundation in numerical methods provided in the Mathematics, Computing and Statistics module. The organic chemistry in the Physical Science modules is logically developed in the Semester 3 Metabolism module but is more directly a foundation for the Molecular Synthesis and Degradation module which discusses the principles of synthetic chemistry and chemical structural analysis with particular reference to environmentally significant points such as the chemical reason why the herbicide 2,4-Dichlorophenoxyacetic acid is contaminated before purification, with the teratogen (monster-former) 2,4,5-Trichlorophenoxyacetic acid. This "thread" continues with the Analytical Techniques modules which will discuss methods of quantitative analysis of various compounds with particular emphasis on pollutants. This thread, like the others, provides an essential background to the third year Environmental Studies modules and also, by way of Animal Physiology and Plant Metabolism and Developmental Biology for the Toxicology and Ecology specialist groups.

The final "thread" of the degree begins with the first year Environmental Studies module. The topic of this module is an "ecological history of mankind", it is intended to demonstrate clearly how the biological, physical science, mathematical and economics aspects of the degree programme come together in one field of study viz. an overview of man in an ecological, chemical, physical, economic and cultural context. In order to ensure that a balanced analysis of these factors is presented to the students we use a team teaching approach in this module with a biologist, a physicist with special interests in energy resources, a chemist with special interests in pollution and an economist/sociologist all being present in each class. The need for team teaching for this module was readily recognised but it was then necessary to decide on an approach at the actual lecturer/student interface. One basic type of approach was the "Morecambe and Wise" approach in which the lecturers interrupt each other as and when it seems necessary and in a completely unscripted fashion. Although this approach is being used successfully by the two lecturers in the Design of Experiments (Semester 4) module it clearly was not appropriate at the first year stage hence the four, year one Environmental Studies Lecturers have chosen a very carefully scripted relationship. As an example of the way this team teaching functions I will cite one group of lectures which begin with "The origin of the earth and geological evolution" which will be taught entirely by the physicist (who has a background in geophysics), the next lecture is "The emergence of organic chemicals and life itself" which involves a twenty minute introduction by the chemist talking about the origin of organic compounds, a five minute discussion by the physicist of the properties of coacervate droplets and a twenty five minute presentation by the biologist about the origin of life itself. This type of approach continues for the whole of the programme of this module so that on some occasions each one of the lecturers will have a whole lecture period talking on his own, while on other occasions two, three or even all four lecturers will make contributions to a single

lecture period. This team approach emphasises to the student the point that the traditional single subject honours qualification of the teaching staff does not provide enough breadth of background for any one of them to take sole responsibility for the course (although one of our graduates could do so) and also provides the lecturers with the opportunity of re-training themselves to appreciate the other disciplines. This latter point is particularly important for the tutorial sessions in which each member of staff has separate discussion with a quarter of the class. Although for a first year course it would have been possible for one lecturer to "get by" after some preparation on the aspects of the module which are outside his specialist area it is inevitable that ultimately the students would become aware of the fact that he was trying to present a physicist's, chemist's or economist's viewpoint and the result might well be the failure of the module to emphasise the point that each student must learn to think from a broad based viewpoint in a way which traditional single subject honours graduates can rarely do. The first year Environmental Studies module, in addition to fulfilling the key function of drawing together the "threads" of the first year course also lays the basis for the second year studies in Environmental Economics and the History of Human Society in Britain, this thread leads, of course, to the third year Environmental Studies modules and also, if the students so choose, to the Environmental Economics specialist group and/or an appropriate independent student project.

It will be clear from all that has been said that, in many senses, the keystone of the whole degree is the third year Environmental Studies modules. These modules provide 180 hours of teaching time which will be devoted to a demonstration of the unifying capacity of a systems analysis approach to environmental problems. Broadly speaking any orderly analytical study designed to help a decision maker identify a preferred course of action from a range of possible alternatives can be called a systems analysis. It has become a routine matter to develop quantitative models to aid decision making about "small" problems such as routing of transport, weapons systems optimisation and so on but it was generally thought that the principles of these "simple analyses" could not carry over into the fields of strategy and policy planning and that these areas were "arts" arrived at through experience and "gut" feeling. Since the early 1960's however there has been substantial progress in this area and we have seen a marked increase in the extent to which analyses of policy and strategy have influenced decision makers on the broadest issues. However, there are still areas where computational techniques can only help with sub-divisions of the problem under investigation, e.g. whether the needs of intercity transportation are better served by improved high speed rail transport, higher performance motorways or inter-city airways, leads to problems which involve far more than the efficient allocation of resources amongst alternative uses. These problems are not soluble in the same sense as efficiency problems in which one can optimise some objective function but rather that the objectives or goals of the action must be identified first and to achieve these goals some very objective judgements must be made. Clearly then we must indicate why the systems approach is a "better" or more useful means of assembling evidence for decision making about Environmental issues than the more traditional methods. The special virtue of the systems approach is that it permits the judgement and intuition of the experts in relevant fields to be combined systematically and efficiently. The essence of the approach is to construct and operate within a "model", an abstraction of the real situation. Such a model which may vary in form from a computer simulation to a purely verbal "scenario" introduces a precise structure and terminology that serves primarily as an effective means of communication, enabling the participants in the study

to exercise their judgement and intuition in a concrete context and in proper relationship to others. Further, through feedback from the model (the results of computation or the critique) the experts have a chance to revise early judgements and hopefully arrive at a clearer understanding of the problem and its context.

The process of analysis will include:-

1. The objective (or objectives)
2. The alternatives
3. The "costs"
4. Models
5. Criteria by which to rank the alternatives

The iterative process involved is represented diagramatically in figure 2. Once the most promising alternatives have been determined these can, in turn be introduced into the model and once the pro's and con's have been weighed a ranked series of alternatives is produced. The sceptic would say that this process has been used by decision makers throughout time but the essential novelty is that until recently this sort of analysis has not been used to treat an *entire* complex problem systematically with an emphasis on explicitness, on quantification and on the recognition, of uncertainty. Also novel are the schemes or models used to explore the consequences of various choices which are now possible with the almost universal application of computers. Poor studies are still possible if the objectives or criteria have been incorrectly identified and the characteristics of good analyses are:-

1. Intersubjectivity . . . . . Results obtained by processes which can be duplicated by others to obtain the same results.
2. Explicitness . . . . . Use of calculations, assumptions, data and judgements that are subject to checking, criticism and disagreement.
3. Objectivity . . . . . Conclusions do not depend on personalities, reputations or vested interests and where possible these conclusions should be in quantitative terms.

The teaching in these modules will involve a team of five lecturers (a mathematician specialising in systems analysis, an ecologist, a physicist with interests in energy resources, a chemist with interests in pollution and an economist/sociologist). There will be a series of lectures describing the philosophy of and scenario for using a systems approach followed by analysis of a series of very simple systems. After this initial work the group will be launched on a major case study in which the importance of all aspects of the course to the environmental theme will be emphasised. A sample case study proposal prepared by Mr T.F. Jones and the module team follows:—

Theme **Air Pollution in Cities**

Definition: "Any atmospheric disturbance resulting from human activity which has a modifying effect on the role which air plays as an abiotic element of natural ecosystems"

1. **Formulate Goals** The control of pollution

2. **The Alternatives** No control of pollution: e.g. Natural recovery of ecosystems as changing technologies change type of pollution.

3. **The 'Costs'** Damage to People
Insects and Animals
Plants; Property;
Climate, etc.

Assignment 1
Investigate a particular area of damage.

4. **The Models**

Sources of Pollution

Energy Conservation

Power Generation, transport, heating, etc.

Industrial
Smoke and effluent.
Heavy metals – Hg. Pb. Cd. etc.
Radioactivity, etc.

Airborne
From external sources.

Construction
Urban development
demolition, etc.

Chemical
Insecticides, etc.

Assignment 2
Investigate a particular aspect of pollution source in depth, e.g. Traffic emissions. See Fox, M. on Leicester City Traffic.

Build models for analysis and decision.

Examples

Smog Smog and particulate matter
Smog and Toxic elements
Climatic effects –
Atmospheric circulation, Inversions, etc.

Radiation Effects, e.g.
Correlation of mortality with fall-out of Strontium 90 using soil measurements.

Climate Simulation models of air movements containing pollutants and particulates and predicting ultimate deposition of pollutants

Damage to Ecosystems Charting airborne pollutants from specific industrial complexes e.g. steelworks and surrounding damage to agriculture and forrestry.
Los Angeles and San Bernadino
Forests

Accidental Discharge Explosion, leakage, etc.
Problems of Nuclear Power stations
Radio-active wastes, waste gases, etc.

Noise and Third London Airport studies

Population Models

These studies would involve scientific, economic and mathematical analysis and would also be a basis for **assignment 3.**

These Assignment studies would lead into an investigation of the synergistic effects of pollution:—

"Are the combined effects of several pollutants multiplied rather than added".

5. **Control Policies and Technologies**

Pricing Systems
Evaluation and allocation of currently unpriced costs and benefits, e.g. emission reduction awards; taxes; compensation requirements.

New Legislation
Clean Air Acts
American Car Emission Control Laws
Factory Acts, etc.

Re-design to control Pollution
Smoke Filters
Re-cycling of waste, e.g.
Biodecomposable plastics, etc.

Re-design of Cities
Location of industries, living and recreational areas, etc.
Air conditioning, district heating, etc.
New modes of living (see Compact City)
Reduction of energy requirements

Re-Education

6. **Feedback into**
Further Assignments
model

7. **Summary**
and discussion

121 This degree programme should produce graduates with high standards of numeracy and literacy, with well developed capacities of communication and perhaps most importantly, with great flexibility of mind. This latter is likely to be a crucially important attitude for new graduates entering posts which will almost certainly alter substantially in the next ten to fifteen years. A proportion of the graduates of this course are likely to occupy posts which do not exist at the present time. The broad basis of their training will provide them with a flexibility not available to graduates of the traditional single subject honours degree programmes. To illustrate this last point we might note that many graduates of single subject honours degrees in biology do not have strong backgrounds in chemistry, physics and mathematics but we tend to find that biological research makes increasingly great demands on knowledge from these areas. The carefully integrated training which our students receive in all of these disciplines will make them particularly well equipped for employment on "interface" problems even though they may be non-environmental in nature.

In summary we feel that graduates from this programme will be ideally equipped to provide economically sound scientific expertise for an environmental team and also that their training will make them better able to handle many non-environmental problems than are graduates of traditional single subject honours degrees.

FIGURE 1

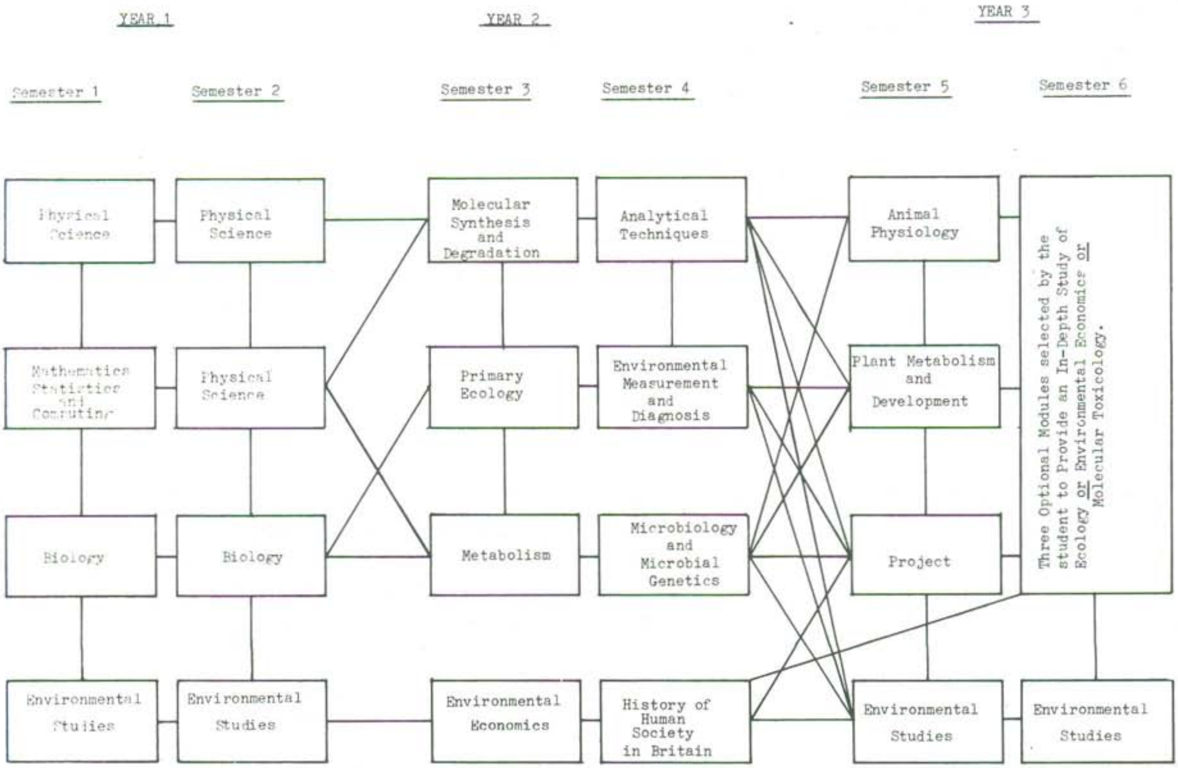
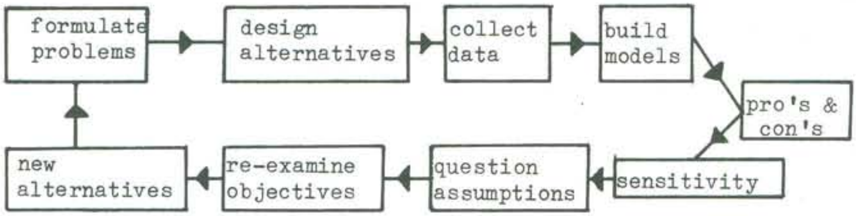


FIGURE 2



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