

THE PROBLEM OF CONFLICT BETWEEN SPECIALISM AND GENERALISM IN CHEMICAL EDUCATION

H. F. HALLIWELL

University of East Anglia, Norwich

At the beginning of a week when we shall be talking about—and arguing over—a range of interesting and effective schemes, I make no excuse for pleading for consideration of purpose *from the students' point of view*.

The problem, which the title indicates, is one which is partly a matter of values but, to my mind, much more one concerned with a gap in the programme by which we meet our responsibilities. For this reason I shall not deal with the details of the excellent courses which have evolved in some universities, but rather with matters of purpose, strategy and tactics of our planning for learning.

It has become common to refer to education as a nation's most important industry. There are some who are revolted by the use of this noun, but, whether we like the label or not, it is a fact that there is an input from society and an output into society with a great deal of planning, money and effort going into the intermediate process. Moreover, by taking such a view help is gained from some of its perspectives. I wish to refer to three.

The first is that it is a very peculiar industry: its raw materials (at university level) arrive differently conditioned by the social environment from generation to generation; but even more importantly its products are its consumers, they will soon be part of the body of shareholders and some will eventually be works-managers and directors. Further, the educational counterpart of market-research and consumer-research will demand more and more of our attention—indeed I believe we can ignore this matching of scientific education with the wider needs of society only at considerable peril. In many of the technologically advanced countries the image of science has fast begun to lose its glamour both for the young and for the educated non-scientist¹. The wonder of intellectual control over the mechanism of natural phenomena is beginning to be shadowed by an apprehension of the consequences of the use of the power which it gives. The clock cannot be put back and I see no solution but through dispelling ignorance. But what is happening?

When we look at our own immediate operation in this industry—education through science and in particular through chemistry—we see that it has, in common with some other areas of university learning, two characteristics:

- (i) it has a degree of sophistication which makes it suitable only for a minority of a minority;
- (ii) it is the result of an accumulation of limited outlook which has resulted in a structure of inward-looking selectivity.

The question which must be faced by universities in their science teaching programmes (the research programmes are quite another matter) is whether the period when much more widespread enlightenment about science is needed is the time to continue along the road to isolationism. Figures² for the U.K. will suffice here for illustration: of every 1000 children learning some kind of science at the age of 14 (and they are in the top three quartiles of ability range), only 70 are studying chemistry at the age of 17 and only 10 continue to study chemistry formally after leaving school. This picture of selectivity is well known and indeed often a source of pride and joy. Whether such pride and joy is wisely based is not a matter I want to pursue at the moment: I want to point out the empty space in science education—the other 60 or 70 capable intelligent young people in the 1000 who have had no education in science at any level but the very lowest. Within that empty space lies the problem I wish to stress.

Before taking the problem up in more detail there is, however, one more phenomenon in educational activity which has its counterpart in industry. All such major enterprises show a complex pattern of interactions between their constituent sub-activities. Either change or no-change in chemical education in universities affects numbers of intake, distribution of financial and human resources, chemical education in schools: we should do well to analyse the consequences of action and inaction. The application of systems analysis used in industrial planning to educational activities has begun to be developed particularly in the U.S.A. and some picture of its working³ is given in *The World Educational Crisis* by the Director of the International Institute for Educational Planning—a division of the U.N.E.S.C.O.

Now let me return to the main theme of my talk: the problems of the empty space and of the chemistry specialist and non-specialist. The words 'specialist' and 'non-specialist' indicate a categorization of people. So do the words 'capable' and 'less capable'. So do the phrases 'worthy of consideration' and 'less worthy of consideration'. I suggest there is a danger in any tendency to regard these categories as identical. There is an even greater danger in ignoring the empty space among the non-specialists. By non-specialist chemistry, or subsidiary chemistry, or minor chemistry, whatever phrase we use—we think of chemistry for those who need it as a tool subject for their principal interest. Only in a few cases do we think of chemistry for the man who is not going to use it specifically either as a vocational subject or as a tool subject—the non-scientist.

It is accepted that a young university student should read history or philosophy, or literature—and not because he is going to be a professional historian or philosopher: he intends to be a business man or a politician or a journalist. I have heard scientific colleagues deplore this situation saying that such people would do well to know something about science, seeing they are going to be an influence in a scientific age. Yet it is only here and there that universities have initiated in science, and in our subject of chemistry, courses designed to meet the needs of that large and, I suggest, very important section of the non-specialists, the non-scientists.

In many countries the majority of those who become leaders of thought and action in society take courses at college or university which omit science. The option is seldom available; but, of much more importance, such people

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of future influence have turned their backs on science—indeed have often been repelled by it. I think a major concern of institutes of higher education must be to see that there is acceptable education through science made available for non-scientists.

I can now more precisely formulate a major problem: to bring about a university education through science which meets the needs of the majority as well as providing a basis of specialized training for a minority, and to decide what part should chemistry play in this replanning.

Replanning it certainly involves. To suggest a course that is merely an emasculated version of that suitable for the specialized training of the few would be disastrous. If, however, there is to be major replanning—and replanning in an area where we are still very ignorant of the major factors which would help or hinder our endeavours—then at least we had better look for general guide-lines. Elsewhere⁴ I have attempted to indicate such, and these have been used in a recent I.U.P.A.C. report⁵. Replanning can be broken down into four, mutually influencing, areas of differing criteria of judgement and differing techniques of production:

- (1) statement of general AIMS which must be translated into OBJECTIVES operationally defined in terms of a student's behavioural patterns,
- (2) ACTION, through the development of a programme of learning situations, to achieve the objectives,
- (3) ASSESSMENT of the extent to which both the scheme and individuals have achieved the objectives,
- (4) machinery for ADJUSTMENT of the proposed programme in the light of feedback from the assessment.

In this simple, bald form the suggestion seems obvious—even trite—and far from new: it is the mutual interaction of the four As that makes it a powerful tool, and its application that can make it unacceptably revolutionary to some for it exposes to our own and to public scrutiny the justification of our intentions, the efficacy of our schemes of learning and teaching, the validity and reliability of our machinery of assessment (usually examinations), and our reaction to evidence for the need for change. Formidable though this may suddenly become when applied to teaching, isn't it exactly similar to what we claim is proper in the field of research?

However, let me elaborate the point of mutual interaction which I have claimed makes the analysis powerful in application. The statement of aims in non-operational terms is a familiar exercise and therefore a comparatively easy matter. The translation into operational terms is as yet a relatively unexplored area and is difficult. We can say that we want our non-scientists 'to understand what science is about', 'to appreciate the part that science is playing, and can play, in society'. But we can objectively judge a man only on observable phenomena—on what he writes, says and does. What is it that one man writes or says or does that another man doesn't, and what is it that the first avoids writing or saying or doing, that the second is prone to that makes us agree that the label 'he understands or appreciates' shall be put on the first, and 'he does not understand or does not appreciate' shall be put on the second? If such questions as these are answered, we and students know what is being looked for, and we and they know what to work towards. What is it that we want our specialist scientist, our non-specialist scientist

and our non-scientist to be able to *do* as a result of working with us?

There is also the second question: 'in what areas of knowledge do we want them to show these abilities?' There is thus at least a two-dimensional chart of objectives. One axis indicates the intellectual and manipulative abilities we want to see developed, and the second indicates the content-areas in which we have decided they should be exercised. To these could be added a third axis—the extent to which an individual student has achieved these objectives. A profile of achievement is thus produced and this is what we mean by a student's examination record. I have two comments to make on this procedure. First, in the past, attention has been almost exclusively concentrated on the subject content and a detailed statement of this is what has been called a syllabus. It is in almost all cases singularly useless as a guide either to learning or to teaching since what a student should be able to do with his information is usually lacking. If both these sets of specifications have not been clearly stated previously, how can we hope to plan the new courses necessary to meet the greatly varying needs of the specialist, the non-specialist and the non-scientist? My second comment is this. Because I approach the question of education from the point of view of purpose for the student, I see the usually omitted specifications (what we want a student to be able to do) as the more fundamental. They act as a basis for selection and rejection of items of content. Lack of discrimination on our part as to what content is necessary to achieve the objectives and what is enrichment is the major factor leading to overloading. There is a very great and hidden danger that everything which intrigues us is regarded as necessary.

But if it has been decided what we want them to do and the areas in which we want them to show these abilities—and the judgements involved there are predominantly sociologically based—then we must see that any testing of achievement which is used has been proven to be both a valid and a reliable instrument for assessing the extent to which just those abilities in those fields have been achieved—and here the judgements involved are predominantly mathematical. What is important for my point is that the difficult task of identifying operational objectives is aided by exercising ourselves in the qualitative and quantitative analysis of their assessment; and certainly the latter exercise is of doubtful use if the former identifying has not been attempted. The point is they each develop in clarity because of the feedback from the other.

But further, if we not only know what we want students to be able to do and the areas in which we want them to show these abilities, but we and they are also clear that these skills, intellectual and manipulative, will be the basis of assessment, then we can devise schemes of learning situations designed to these ends. Here the activity chiefly involved is imaginative, creative and pedagogic. To misquote the Scriptures 'of the making of schemes of study there is no end', but we now have a criterion of rejection and selection: can the schemes proposed be shown, by the methods of assessment we have tested, to have achieved the objectives we have laid down?

The feedback from these exercises will indicate more clearly where we have been inadequate in our first attempts and also will indicate more precisely what adjustments are necessary. Change can be deliberate and less tiresomely haphazard and more often can be planned before the moment of panic.

The analysis of procedure which I have just outlined is of general application, appropriate equally to the planning of a four week long piece of work with schoolboys and girls of twelve years of age as to the functioning of a university as a whole. It must be obvious that it does not give an answer to the question what should we do—the outcome will be diversity not uniformity—but offers a way of finding an answer which has objectively checkable internal consistency.

Let me return to the problem of chemistry for the non-scientists. Some twelve years ago, Professor I. T. Millar and I as lecturers in the chemistry department at the University of Keele in the U.K., were concerned with just this problem, for the regulations of the university required that students reading humanities as principal subjects should take an experimental science in addition. What were we to do? These students had some years previously chosen to turn their backs on science and we rebelled at the idea—if I may twist an English expression—of making sow's ears out of silk purses. We decided that our students might find their history or politics, or whatever their major interest was, the clearer and richer if they could discuss with clarity and justification what difference there was between such statements as 'I believe in God', 'I believe in democracy', 'I believe in causality' and 'I believe in the molecular theory'. The eight weeks course was based on experimental work, on the interpretation of observations, on discussion of the ways that scientific ideas had evolved and on the types of factors which bring about such changes. It was also concerned with the comparison, in the realms of science (which we supplied), or politics and literary criticism (which they supplied), of criteria of acceptability of perspectives and of techniques of collecting evidence. In passing I may say that we were both surprised at the level of the students' experimental skill. Feedback from successive groups of students indicated that they too were surprised at their enjoyment of the course and at the enrichment it had made to their principal interest.

This was a very amateur beginning, but I believe it had the rudiments of what we are now searching for—pertinence of student involvement. Since then Professor I. T. Ramsey of Oxford has published *Models and Mystery*⁶ in which he discusses the use of models by the experimental scientists, the social scientists, the creative writer and the theologian. I can see the possibility of a fascinating course in chemistry for non-scientists based on the ideas of this professor of the philosophy of christian theology: nonetheless I would want to organize my proposals along the lines of the four As which I have outlined.

There are many other such explorations going on in universities all over the world. What we need is some machinery, and time, so that we can share our data, look for a pattern in them and make the findings freely available. We have yet to investigate much more fully the relationship between courses for specialists, non-specialists and non-scientists, and I believe many of the misunderstandings between those who are planning programmes would be cleared if we were to work out, along the lines I have suggested, the implications of Samuel Alexander's advice: 'Liberality in education is a spirit of pursuit not a choice of subject'.

But supposing we have a scheme so worked out, there is still the problem

of putting it into action. The factors helping or hindering our efforts are numerous—and sometimes powerful. Professor J. A. Campbell who has done so much in the realm of development of chemical education shows his interest also in the kinetics of reactions when he urges us, in any production exercise, to pick out the rate-controlling steps. I think there are four areas of high energy barriers:

(1) the young academic knows that his opportunities for promotion are through his research: professionally it pays poorly to be interested in education;

(2) there is a resistance to formulating aims in terms of operational objectives because it leaves one naked and vulnerable;

(3) there is still a great deal of ignorance about the learning processes of the university students.

I strongly urge universities to make it clear, by making time and approval available and by not leaving these important matters to be undertaken in occasional free time, that they encourage some of their staff to involve themselves, at least partly, in the problem of university education through their subjects. This is already being done in some places: it needs to be more widespread and coordinated.

In conclusion I return to my title: the problem of conflict between specialism and generalism in chemical education. In our minds there may be a conflict which arises from the frustration engendered by the inadequacy of our discrimination; there may be a conflict in students' minds arising from what they, rightly or wrongly, feel to be the irrelevance of what they are asked to do—but I don't see any conflict between schemes of work indicated by the labels specialism and generalism. I see only a differentiation of objectives and programmes of study devised for their achievement. They meet different needs. Both are worthy of our highest regard and endeavour.

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