ROUTLEDGE REVIVALS

The Teaching of Science

Education, Science and Society

F. R. Jevons

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First published in 1969, *The Teaching of Science* primarily deals with science teaching in secondary schools and universities, but its searching discussion of criteria concerns all who have to do with education. The concise but well-documented treatments of the nature of the scientific process and of the social implications of science will be of interest to many scientists and especially useful for teachers of general studies. Professor Jevons looks first at *why* we should teach science and thereby sheds light on the more immediately practical problems of *how* it should be done. He thus does more than merely add to the already large volume of exhortation to make it more attractive and intellectually stimulating.

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THE TEACHING OF SCIENCE

Education, Science and Society

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TO JOHN AND MOLLY JEVONS

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FOREWORD

This book owes a good deal to the vantage point from which I have written it. Accordingly, I would like first to express my gratitude to the University of Manchester for creating the new type of Department of which I have since 1966 been the first head. The Department of Liberal Studies in Science was set up at the initiative principally of the senior professors of physics and chemistry, B. H. Flowers and G. Gee respectively. It is responsible for a course of studies which (for reasons which are pointed out in section 4e) is known colloquially as 'Science Greats'. This undergraduate course is designed primarily to help young men and women to bring a scientific background to careers outside the laboratory (see sections 3h and 3i). The main subjects taken by students in all three years are physical science, which is taught by members of the physics, chemistry and engineering staffs, and liberal studies in science, which is defined as science looked at from the economic, social, historical and philosophical viewpoints (see section 5i). The mere fact of being in an environment in which science is looked at in these ways has naturally helped to focus my attention on the broader setting of scientific and technological education of various types.

Specific references to the activities of the Department of Liberal Studies in Science are made in note 36 to chapter 3 and in notes 13 and 38 to chapter 5. I am keenly aware of the debts I owe in many ways—for help, information, ideas, stimulation and support—to my colleagues in the Department, W. G. Evans, M. Gibbons, J. Langrish and H. Rothman. The students in the Department in the first two years of its existence have also helped me to form my views.

Further afield, I have learned a great deal from colleagues in other Departments of the Faculty of Science, in several Faculties other than Science, and in such important peripheral bodies as the Manchester University Appointments Board and the Northern Universities Joint Matriculation Board. Some names that spring to my mind are those of W. J. D. Annand, G. N. Burkhardt, A. J. Cain, D. S. L. Cardwell, J. Diamond, L. A.

Gunn, B. J. Holloway, H. S. Lipson, W. Mays, G. Murray, A. Pearson, E. H. Robinson, R. Williams and J. C. Willmott. This list is certainly not exhaustive.

I would like to thank Dr Dainton and the secretariat of his committee for allowing me to have a draft of their report before publication. Finally, I am grateful to Miss Margaret Bruce, who typed most of the manuscript, for her endearing ability to read my handwriting.

F. R. JEVONS

September 1968

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CHAPTER ONE

WHY TEACH SCIENCE?

It is my intention in this book to assess the enterprise of teaching science by first examining what lies at the other end of the educational road. One cannot properly decide what is good and what is bad in education without considering its aims and purposes; and that means, in this case, looking rather hard to see what is done with science not only by scientists themselves but also by society at large. Before finding faults and preaching improvements, it is as well to consider not only how it is taught but also what it is taught for.

This is not an easy undertaking. The purposes themselves are many and complex, and the relation between means and ends is indirect. But science stands in an interestingly intermediate position here. It is neither so directly vocational that the matter is not worth discussing except in purely professional terms, nor is it so non-vocational that it is impossible to discuss except in terms of airy idealism. The answer is neither made obvious by the prospective job content, nor is it so completely elusive that it is best for the teacher to trust entirely to luck and instinct. Two cheers for luck and instinct, but also one for the clear formulation of objectives.

The importance of the task is obvious enough to need no elaboration here. Both in social and economic terms, the stakes are high. The teaching of science is expensive, and the rewards and penalties for doing it well or badly could be breath-taking. Science can easily make or break the future for mankind.

The real problem to be faced first is to analyse what success consists of. It has become fashionable in some quarters to talk about the 'cost-effectiveness' of education, and to try to assess the efficiency of the educational system by some form of input-output analysis. With regard to such attempts, there should certainly be some sympathy at least with the aim, for there is

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undoubtedly a good deal of misdirection of effort and underutilization of resources; but at the same time it is important not to underestimate the uncertainties. When the calculations of costs have been done—and that in itself is not as easy as it may sound, at least in the case of higher education—the biggest difficulties and the most vital issues still remain. They arise in trying to describe and define—let alone quantify—the effectiveness or benefits or output. Economists admittedly show more ingenuity than they are commonly given credit for in putting money values on things that appear not to have any. But it is necessary always to look most carefully at the criteria. Attempts with imperfect criteria could lead to plausible half-truths and thence to disaster; for while outright errors are at least liable to be detected before too long, half-truths are doubly dangerous by virtue of their insidious powers of persuasion.

Clearly it should not be the sole aim of school and university reform to maximize the output of school-leavers and graduates for given inputs of educational manpower and money. Much depends on the qualities and types of people that emerge from the educational system. But what qualities and types should we try to produce? It is hardly worth while trying to say without examining the functions they might perform, and the requirements for performing those functions well.

So the primary theme of this book is *why* we should teach natural science in our schools and universities. The more immediately practical problems of *how* it should be done are matters on which a certain amount of light should be shed in consequence. I do not want merely to add to the already large volume of exhortation to make the teaching of science more attractive and intellectually stimulating, and to supply a necessarily personal prescription for the way to set about doing it. There is no unique prescription, because there is no unique objective. The objectives are varied, and they are interrelated in complex and not always obvious ways. Hence there is liable to be confusion over the nature of the considerations that are important in designing scientific education, the criteria to be applied and the factors to be balanced. If these matters can be brought into sharper focus, the problems can at least be formulated in clearer terms, and that should go some way towards solving them.

WHY TEACH SCIENCE?

One obvious reason for teaching science is that a lot of scientific knowledge is available. The accumulated stock of knowledge about natural science is a significant part of the human heritage, and younger generations are given the chance to share in it by including it in accepted patterns of study in the educational system. This argument might be called the 'Mallory argument', because it boils down to the reason Mallory gave for wanting to climb Everest: 'Because it's there'. The mere existence of knowledge is taken to be a sufficient reason for teaching it.

The trouble with this line of approach is that it gives no basis for deciding between different areas of knowledge. All bits of knowledge, the implication is, are born equal and have equal rights to be taught. Some basis for choice is, however, essential, given the obvious gross disparity between the amount of knowledge available and the capacity of the human mind.

If one could summon up before the mind's eye the whole vast panorama of human knowledge, and if one could push aside all the problems of teachers, buildings, equipment and timetables (wishful thought!)—in such ideal conditions, which areas of knowledge should one choose, and on what criteria, to teach to young people at school and university?

Trying to answer this question leads immediately to an even wider one. Why teach anything at all? A question as sweeping as this is likely to get correspondingly general answers. It tends to elicit hints of man's 'highest' functions and the features that distinguish him from animals.

The suggestion of evolutionary significance here means more than might appear at first sight. Philosophers of biological evolution have read a deeper significance into the teaching process[1]. It can be said to mark a new and enormously important development in evolutionary history—not just a step in evolution, but a new departure in the evolution of evolutionary mechanism. The teaching of the young by their elders, which has been elaborated by the human species so much more than by any other, is a fresh channel through which the experience of past generations can help to shape future ones. With person-to-person learning (as in apprenticeship) supplemented by the inventions of writing and printing, a very effective mechanism has been provided for making available to new members of human society the whole accumulated knowledge and under-

standing of the past. It amounts, in effect, to a new mode of heredity. Human young are equipped by their ancestors not only with sets of the traditional genes, shaped by millions of years of natural selection, but also with a new kind of 'genes', the facts and concepts of some two and a half millenia of scholarship.

Seen in this light, the facts and concepts of science and its ways of thought can certainly be ranked as particularly important. Since it is obvious enough that science is one of the major forces for change in the modern world, its 'genes' have particularly powerful evolutionary effects; so they form specially significant factors in the new genetics of the intellect.

Such thoughts are impressive, and help to bring home the grandeur of the whole enterprise. Perhaps it is as well, nevertheless, not to be too easily carried away by them[2]. Against the background of the vast sweep of evolutionary history, the individual might tend to get forgotten; and education has, of course, to do above all with individual people. All good education aims to promote the self-fulfilment of individuals—to draw out their innate potentialities according to the literal meaning of the word 'education'. Teachers of science in particular need to keep this fact near the surfaces of their minds, for their subject has in many quarters a reputation for being coldly objective, inhuman and impersonal. There is a story of a science teacher who forbade the use of the first person singular because he wanted 'a description of the experiment, not an autobiography'. Trivial though this anecdote is in itself, the significance of what it implies is momentous. It will be worth while later to enquire into the origins of the attitude, and its wider implications (section 2b).

One argument for teaching science might be that young people want to study it. So they do, in large numbers—but apparently the popularity of science shows some signs of declining (section 4h). Is science acquiring a public image of dullness? Do people who study it just grit their teeth and grind their way through it in the hope of something pleasant or profitable at the end?

If so, the fault can hardly lie in the subject. The idea that science in itself might be dull is just not worth considering seriously. How can there be a lack of inherent interest in one of mankind's greatest achievements—an activity which has attracted a good share of what are recognized as the greatest

geniuses that the human race has produced? One could as easily argue that art and literature and music are dull. If science appears dull to students—to the extent that it might be acquiring a reputation for dullness—it *must* be the fault of those who present it badly. It is important, therefore, to try to diagnose the causes of failure (sections 2d, 5d and 5e).

The interests of individuals cannot be properly considered without reference to factors outside them. Few young people want to become hermits or pillar-saints; teachers do not in general want to produce such oddities, and educational systems are not designed to do so. Education has to be planned, therefore, with some reference to the places that those being educated might come to occupy in society and the sort of roles they might be called upon to play there.

How far it can or should go in this direction, however, remains a wide open question that requires careful examination (sections 4b, 4g, 5b). The needs of society are represented in the first instance largely by the preferences of employers, but employers' statements about them are quite liable to be ill-informed, short-sighted or misguided. The variety of possible jobs far exceeds the number of different types of education that it is practicable to provide. Even if it did not, there is a great deal that is required for career success that it is just not possible to teach, even if one were prepared to sweep aside quite ruthlessly all ideas about what constitutes a proper 'intellectual discipline'. The 'fit' or 'match' between what the educational system provides and what employers want is, therefore, at best a highly imperfect one. In specific knowledge, particular skills and general attitudes, raw school-leavers and graduates are poor approximations to ideal employees.

It is by no means self-evident, in any case, that the attempt to match education as closely as possible to prospective employment is not a misguided one. Closely matched education tends to become description of the way in which a certain function is carried out—'how it is done'. As such, it is liable to generate fixed ideas and inflexibility. By concentrating on 'how it is done' it might divert attention from 'how it might be done better'. One can easily imagine, for instance, how undergraduate courses on dough-mixing machinery or polypropylene technology might retard rather than accelerate progress in those fields, and how—

as a converse of that—people who had put all their educational eggs in those baskets might find themselves at a loss when change eventually does come, as come it must.

So the best fit between education and job content may well be a loose one; and the higher the level of the post, the looser one ought perhaps to make the fit, since higher grade posts deal with wider and less clearly defined areas. Taken to its logical—or at least extreme—conclusion, this argument would demand that the highest education should not aim at a fit at all. Universities should then take essentially no account of career opportunities in deciding what and how to teach. Ideally, they would teach only the least vocational subjects, such as history and classics, which are rather strictly non-vocational (except for the possibility of going on to teach the same subject as part of a self-perpetuating and intellectually closed system). Higher education would be purely generalist in aim, even though it might be specialist in execution, if it were judged that non-vocational specialization in history or classics is the best way to wring the educational benefits from these subjects (sections 4g, 5a). No match would then exist between education and employment except in the most generalized ways such as verbal skills in the use of language and those skills, even harder to pin down precisely, which go to make up a 'well-trained mind'. Universities would become ivory towers of scholarship and learning, quite independent of outside pressures.

This kind of view has obvious attractions and does not lack persuasive supporters, so it is as well to note an important difference between the two main lines of justification for it. On the one hand, it is said that it is pleasant for society to be able to support scholarship for its own sake, as a luxury not justified on economic grounds. Few people would take exception to this as a matter of principle, and there is room for argument only about the extent to which any given society should afford to indulge itself in this way, given that it is bound to want other expensive luxuries as well, such as fine arts or old age pensions. On the other hand, it is also said that it is best for the intellectual development of students to be immersed for a while in an environment where disinterested scholarship is paramount, sheltered from 'distortion' by external considerations and values. Here the argument is in terms of effects on students, so there

may well be an economic or social pay-off in terms of well-trained minds emerging from the system. The *criterion* is at least partly in terms of a match between education and employment, even though the means adopted are indirect and long-term.

For the educator who is at all career-conscious on behalf of his students, science stands in a peculiar position. On the one hand, it forms a group of widely practised specialist skills on which is based a group of what are by now fairly standard professions. On the other hand, the need for education in science is not limited to the needs of these professions for recruits. The training of specialists should not be the sole objective of science teaching. It is in any case not its major function at the lower levels of the educational system, and perhaps it should not be even at the higher levels.

This consideration forms a major theme of this book. It means that to base educational provision on manpower forecasting in any narrow sense would be misguided. As a debating point, the situation is sometimes compared with teaching the three R's. It is obvious—at least in retrospect—that it would have been wrong to provide for teaching people to write only on the basis of forecasts of the number required as scribes in mediaeval monasteries or as clerks in the offices of nineteenth century capitalists. The case for teaching science is not quite the same as that for imparting the rudiments of literacy, but the differences between the two needs are probably not as great as many seem to imagine, and the value of scientific background for people not in specialized scientific occupations is something that particularly needs to be brought more into the open (sections 3h, 3i and 4h).

These are some of the problems that will have to come under scrutiny in the course of this book. What has already been said is enough to show that the purposes of science teaching fall roughly, though not neatly, under two broad heads. On the one hand, there is the demand for professional practising scientists; on the other, there is also a need for others to be educated in science. In order to help to make these two groups of objectives more specific and to state them in more detailed ways, chapters 2 and 3 examine respectively the nature of the scientific process itself and the wider social implications of science.

When that has been done, however, the task is not over. How-

ever clear the objectives can be made, the ways and means to achieve them do not automatically become obvious. Since the relation between educational means and ends is usually indirect, and often very much so, it may be best in many cases not to aim too specifically at what appears to be the target. Roundabout ways may turn out to be the most effective ones.

The educator himself is—or should be—the real expert here. It is up to him to balance the factors and arrive at appropriate educational solutions. Accordingly, chapters 4 and 5 make an attempt to work out in educational terms some of the complex implications of the analyses of chapters 2 and 3.