TEACHING SCIENCE HUMANELY

by

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A GREAT deal is being written and spoken about the gap between scientists and humanists and many schemes are being worked out designed to bridge it, at both school and university level. Most of the innovators seem to pin their faith on the introduction of additional subjects into the curriculum of the sixth forms or the syllabuses of the universities. Such suggestions lead not only to the vexed question where time is to be found in already overcrowded time-tables for these additional subjects, but it is also doubtful whether the problem can really be solved in this way. If these subjects are still to be taught by specialists as more or less closed subjects there is the great danger that the gap will merely be transferred from society to the individual. This danger is indeed realised by many people. The demand, then, is for a more humane teaching of science and for a consciousness of the impact of scientific thought on the culture of our day when the humanities are being taught. Attempts to do just this have been made in Rudolf Steiner schools for the last thirty-five years. What follows is based on the experience of one science teacher in such a school, who has been privileged to share in these experiments for twelve years, after teaching for some time in a state grammar school. I rather think that success in the attempt to teach science humanely will also go a long way to solve the ever present problem of the supply of scientists and technicians.

The question of time is, of course, also an important one in a Rudolf Steiner school. In fact I am convinced that nothing really satisfactory can be done in humanising science teaching without severely pruning the traditional syllabus. In doing so it is most important to keep constantly in mind that one is trying to select those parts of a subject which it is important for every educated person to know, or which will convey experiences or develop faculties which it is desirable for such people to have. The danger is always that the specialists consider, instead, what they regard as important from the point of view of their science, and the result is a school syllabus which is really the beginning of specialised training in different sciences. Most ordinary level syllabuses of the G.C.E. are rightly criticised on just this count. Even many curricula for general science cannot be excepted: they also stop at far too elementary a level.

A great deal of the research techniques and of the problem-solving which these syllabuses contain is not necessary for a general education. The children must, of course, learn about the methods employed by scientists, and they should also carry out experiments themselves. They should have experienced what it feels like to be faced with a scientific problem and what it means to make an accurate experiment. These aims can, however, be achieved much more economically than is done usually. At present the pupils are required to learn experimental methods in every part of their work. A great deal could be gained by a judicious selection of a few typical experiments or, even better, small research projects if the facilities permit this. It would then be possible to deal with these much more thoroughly and the children would gain a much deeper experience from them.

Problems are, of course, largely introduced because they are supposed to test whether the pupil really understands the subject. Now it is certainly true in general, although not invariably, that a candidate who can solve a problem has also understood the subject. It does not follow, however, that a pupil who cannot solve a problem has *not* understood the subject. Faculties, especially that of translating a concrete situation into mathematical symbolism, are required for solving problems which have nothing to do with an understanding of the concrete situation. Problem-solving is, of course, a good training for the intellect and as such must not be entirely neglected. It is, however, practised in the mathematics lessons, and facility in it develops slowly in many children. There is no reason why difficulties in problem-solving should impede the teaching of science as a cultural subject.

What should then be done with the time saved by putting less stress on problem-solving and on learning many different research techniques? A good deal of it should be devoted to teaching the history of science. Most teachers seem now to agree that this is a most important part of the science syllabus but it is doubtful whether under present conditions many can do more than make short historical references here and there. It is not a question of introducing a connected course in the history of science. This is mainly because the subject has two different aspects which are suitable for different ages of children.

There are first of all the practical applications of science in technology, medicine and hygiene. These have affected our whole mode of living. This is very obvious to us adults and we often forget that it is not equally plain to the children. After all, many of the younger ones can hardly remember a time without a T.V. set. I have found that children from about 12+ to 14+ are particularly interested in the way in which the modern inventions have developed and in how they work. They are also interested to learn how this development has affected the routine of daily life. They seem to ask "how" and not yet "why". In answering this question a great deal of useful scientific knowledge can be imparted. If one takes, for example, the development of the heat engine from Newcomen to jet propulsion, one sees how every new advance was linked to quite fundamental scientific discoveries. The course can be planned so that the most important laws and experiments are selected as a hard core which is really treated in detail, while the whole historical development has to be known more in outline. Such a course can give the children the feeling that science is everybody's concern.

Only at a later age, at the earliest from sixteen onwards, are the children (in my experience) really able to appreciate the second aspect, namely science as a chapter in the development of human thought. All the same it is essential that as many of our pupils as possible are brought to such an experience. Such a course has to be rather comprehensive if it is to be really effective. One cannot appreciate the novelty of modern scientific thought unless one knows what has preceded it. It is therefore necessary to deal fairly fully with Aristotelean ideas both in their original form and in their medieval modifications.

Both in Greek and in Medieval cosmology all sciences are really included. After this they diverge, and the story of the divergence can be linked with the teaching of scientific facts in many different ways. Only one scheme, which I have used with some success, can be given as an example. First it was shown how chemistry and astronomy gradually separated and became sciences on their own, without the obvious connection which they still had in Alchemy. Chemistry was developed up to the Atomic theory and the periodic table, and astronomy up to Newton. Such a treatment shows how the awakening interest in numerical relationships leads to quite a new view of the world. One can see how fresh vistas open up, but also how the essential unity of the universe disappears. The story was continued in lessons on electricity, and was taken up to the end of the 19th century and the dissolution of the simple concept of the atom. Much use could be made of the work in elementary electricity which had been done two years earlier when the development of telegraph and telephone were described, just as in the chemistry course many illustrations could be taken from previous work on acid, base and salt and on some of the most important elements. A study of optics in the last year led to a unification of all the previous work and brought the story up to date. Since the students were all in their 17th or 18th year, and since problem solving was only required from those who were also budding scientists, little difficulty was experienced in introducing material usually classed as advanced. The aim was to give a qualitative treatment of as many of the results of modern research as possible and of the problems raised by them.

Such a course stimulates the interest of the more philosophically inclined pupils. They see that science nowadays gives the philosopher the hardest nuts to crack and that scientific thought in its turn is very much in need of philosophic elucidation. Some of them may experience the present view of the physical world as philosophically unsatisfying. Even the modern youngster is still sufficiently self confident to expect to do better than his elders and this may well result in pupils choosing science as a study who otherwise would have taken up the humanities. But the course is also of the greatest value for the future scientist. A concentrated experience of the way in which theories and modes of thought change gives him a healthy scepticism in the matter of theories, and should make it much easier for him to break new ground later. Our present mode of teaching makes our future scientists far too hidebound. When they leave school they are already indoctrinated with the views accepted at present; it would be much better for them and for the future of science if they had more of Faraday's cautious attitude to theories. In any case no one should leave our schools at eighteen without having some idea about the philosophical implications of modern scientific thought. Too many people are still living in a comfortable nineteenth century universe; modern man must really face the challenge presented by more up-to-date views if he is to play his part in our cultural life. This challenge would, I am confident, bring many more students to the science faculties of our universities.

If the interest of the pupils is to be aroused, the way in which the picture of nature grows is also most important. It should take shape gradually over the years and at every stage account must be taken of the maturity of the child and his interests. At an early age the eagerness of the children to learn facts, to know what is the biggest of this and the fastest of that, can, for example, be used to teach a great deal about the variation in physical properties of different materials. Even if they bore the teacher, tables of expansion coefficients and of specific heats of refractive indices have in my experience a fascination for the youngsters, and arouse questions in their minds. Subconsciously at least they ask how these properties are related to the chemical behaviour of the same substances and to the use which plants and animals make of them. Later on comes the stage where each teacher must know something about the work of the others. When talking about electricity the physicist must be able to point to the work in chemistry and to say something about electricity in the human organism and in electric fish. Only indications are necessary because the biologist and chemist will take up the work in more detail in their subjects. In this way wonder is aroused. As questions are answered at one level, they give birth to new and more profound ones, which are allowed to rest in the mind and are not immediately answered. If many remain still unanswered when the young men and women leave school, all the better. Wonder is the beginning of all scientific quest. At present we tend to send the children away with the illusion that they have learned most of the answers at least in their specialist studies, and that those which they have not learned somebody else knows and that they can look them up in the library. Can we be surprised, then, that they show the lack of interest and initiative of which many employers complain to-day? A wide knowledge of facts and phenomena always raises questions about their connections. If this comes together with the healthy scepticism about theories, which should be imparted by the historic approach, the children will be prepared to enter on their university courses with eagerness and expectation if they become scientists, and they should have a responsible and informed attitude to science if they enter other walks of life.

From what has been said above it is clear that there are two different aspects to the "humane" teaching of science. We must take the word "humane" really seriously and adjust our teaching so that we impart the knowledge and the experiences which our pupils should have in virtue of the fact that they are human beings and not because they may take up this or that profession. As men they must have the right relationship both to society and to nature. We may hope to have done something for the former if we have taught the historical part of the subjects correctly and have thereby introduced the children to the technical achievements of modern science and to scientific thought as a chapter in the spiritual development of humanity. Whether we establish a right relationship to nature will depend at least as much on the mode of our teaching as on its content. Paradoxical as it may seem, I am convinced that an attempt to be too scientific at too early an age can do more harm than good. After all there are two parts to the scientific method. Science starts by induction. Slowly the manifold phenomena of nature group themselves and reveal an underlying harmony, a logically connected body of scientific law, from which we can then proceed to deduction, and thus verification appears only later. In the day to day working of the scientist the two go, of course, hand in hand but in the development of science teaching they should be consecutive. This brings us to the second aspect of "humane" science teaching. We must take into account the facts of human development. In my experience of secondary school science teaching I have found two quite distinct stages which I should like to call the "how-stage" and the "why-stage". The two, as always in natural development, have no absolutely hard and fast boundary but fifteen years is perhaps a good average. Before that age the children seem mainly interested in *how* things work, and *how* they were discovered. Despite some attempts in this direction I have never succeeded in arousing the interest of more than a small minority of a class of fourteen-year-olds in the question why the steam engine was developed just at the time and in the country where it was in fact first used; but I found a great deal of interest in how this happened. When the question *why* arises at this age, the children are usually satisfied by the most immediate explanations, which really describe *how* a thing happens. This is the inductive stage and theories have no place in it. If one tries to impose one's own desire for more fundamental explanations at this age, I think the result is often the all too familiar experience of science teachers that a considerable number of the pupils decide that science is an esoteric study which can only be understood by the few "of whom I am not one". There are, of course, always a number of pupils who are intellectually inclined, and who can be drilled even at this stage to ask the questions which we want them to ask, but this procedure leads to a loss of many potential scientists and is not even healthy for those who can be so drilled. This is the stage when many facts can be learned, and they should be drawn from all the sciences, provided it is done in a way which arouses wonder. The work so done provides the necessary broad basis for the second stage, that of presenting science as a logically connected system. This study can only be brought to a proper conclusion if the children stay until they are eighteen. One of the greatest menaces to good science teaching is the ever growing volume of even elementary textbooks of chemistry and physics which start with the atomic or electronic theories.

Two consequences are apparent from the above. Firstly, the time required for teaching all the sciences in the way outlined—and they must all be taught if it is our aim to establish a true relationship to nature—does not permit the high degree of specialisation practised in most grammar schools at present;

and secondly, it presupposes some form of education up to the age of eighteen. The latter is in any case provided for in the Education Act, and it only remains to implement its provisions. That this can only be done gradually goes without saying. As far as specialisation is concerned and some vocational or pre-vocational training, we have found in the Rudolf Steiner schools that this is not incompatible with general educational courses as outlined above which do, of course, include the humanities as well as the sciences. Boys and girls capable of a university education can by eighteen be brought to the standard of the G.C.E. advanced level in three specialist subjects in addition to the necessary ordinary level. If we also take into account that the necessity of advanced level work for university entrance is only a comparatively recent innovation, and that it is only in England that a degree can be obtained after so short a time as a three-year university course, the solution to our educational problem lies probably in an extension of the latter to at least four years. The advanced level courses could then be remodelled so that they only provide the really essential fundamental knowledge which is much less than the present content of the syllabuses, and an opportunity for the candidate to show in a restricted field that he or she is able to do work of university standard. The universities and employers would then get generally educated people who could specialise against a wide background of knowledge and experience.

In conclusion it should be emphasised that the work described above represents developments of Dr. Steiner's pedagogical indications by one science teacher only and that they owe a great deal also to work done by colleagues in this and other countries. I have also only written about the task of the teacher in humanising the material available in present day science. There is a similar task for the scientist. The high degree of specialisation in the sciences has led to the disintegration of the picture of the universe. Our knowledge of man especially, and of his place in nature, is only a very fragmentary one. A great deal of work is therefore required in the sciences themselves to make them into a truly humane discipline. It may be hoped that pupils who have gone through an education such as that described above will be better fitted to carry out this task than our own generation.