cience in Schools

his edited collection considers science teaching at all levels in econdary schools and the implications for schools of the nature of cience and science activity, including its place in the curriculum nd its relationship to technology. The book is divided into six nain sections.

cience and Scientific Activity examines the nature of science from ne perspectives of scientists such as Einstein and Medawar and of hilosophers and historians of science such as Popper and Kuhn. *cience in a Technological Society* ranges from C.P. Snow to Steven lose; and *Science in Education* from Layton to Ziman. *Science in he Curriculum* discusses general objectives of science teaching and ssues such as why the science curriculum changes and what is the neaning of interdisciplinarity or integration in the science urriculum. *Teaching Methods in Science*, features the work of, mongst others, Driver and Gilbert; and, finally *Review and valuation* looks at how we should evaluate science teaching and urriculum innovations.

cience teachers and trainee science teachers will find this an nvaluable resource which brings together the current thinking nd trends in science education.

Joan Brown, Alan Cooper and **Frederick Toates** teach in the aculty of Science, and **Tim Horton** and **David Zeldin** teach in he School of Education, all at the Open University.

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EXPLORING THE CURRICULUM

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SCIENCE IN SCHOOLS

edited by J. Brown, A. Cooper, T. Horton, F. Toates and D. Zeldin

An alternative idea about the dominant influence on the science curriculum is put forward by Millar, who suggests that science teaching may be predicated on the notion of the 'two mentalities'; a higher intellectual mentality capable of abstract thought and active response, and a lower simplistic mentality that thinks only in concrete terms and responds passively. This notion provides food for thought given the extensive use of mixed ability teaching in Britain's comprehensive schools today.

Accepting all these reasons for teaching science provides a substantial case for maintaining its place in the curriculum. It provides good mental training, it creates an understanding of the natural world and an awareness of the technological world, it helps to supply the scientists who will underpin the country's economy, it is necessary to maintain the scientific academic establishment. Is there, though, a common core of science that should be taught to all children? Two radically opposing views are put forward by Waring and Schofield, and West.

Waring and Schofield are staunch supporters of a core approach on the grounds of both social justice (equal opportunities for all) and the need to safeguard essentials (to ensure the proper use of public monies, to supply industry with scientists and to fit children for science in society). However, West feels that it is highly unlikely that any core science based on the content of current examination board syllabuses which are geared to meet the needs of higher education could prepare children adequately for adult life – either their interaction with science in their everyday lives, or as workers in industry, where scientific awareness may prove counter-productive to efficiency.

15 The changing aims of science teaching

● P. Uzzell

Uzzell describes the influence that major reports, projects and policy statements concerning school science have had on pedagogy. He suggests, in a survey covering more than a century, that dominant theories such as 'science as mental training' or 'science as providing an understanding of the natural world' have found favour at different times. In some instances, the fashion seems best understood by referring to the demands of an industrial society for technological improvement. At other times, it may be necessary to refer in the first place to changes in school organization.

Why is science taught in the way it is? Do the present aims of science teachers owe anything to past ideals or do they just reflect the whims of fashion? A brief survey of the aims of science teaching for the 11–16 age group over about a century gives some fascinating insights, as well as providing a basis for discussion of these questions.

Science was taught in some elementary schools before the middle of the last century. Government grants for purchasing equipment began in the 1840s. The science taught in the 1840s and 1850s was not only concerned with understanding scientific principles of everyday things in the home and at work, but also with the development of logical thinking and the improved use of language. The work of Richard Dawes and Henry Moseley in this connexion was outstanding.[1] However, the climate of opinion towards science teaching in elementary schools became less favourable and the Education Department's Revised Code of 1862 virtually excluded all but grant-earning subjects – reading, writing and arithmetic – from the curriculum.

An influential essay by the Revd J. M. Wilson, science master at Rugby, appeared in 1867.[2] In the essay, Wilson, assuming that the characteristic of an educated man is his power of judging evidence and proof, argued that these were the very attributes imparted by science teaching. Wilson advocated an investigatory approach (which he used himself), beginning with the concrete experimental fact and leading to the abstract, to laws and hypotheses, from the known to the unknown. Despite tireless efforts on the part of Wilson and others, it was many years before these ideas influenced the thinking of the Government, Examination Boards, or many Headmasters.

Not much science was taught in the nineteenth-century public schools, and, with notable exceptions like Rugby, it consisted of verifying laws and illustrating properties using lecture demonstrations. Nevertheless, the Schools Inquiry Commission (1868), while deploring the lack of science teaching in public schools, perceptively stated that

> true teaching of science consists not merely of imparting facts of science, but in habituating the pupil to observe for himself, to reason for himself on what he observes, and to check the conclusion at which he arrives by further observation or experiment. (Report, Vol. II, p. 6.)

Expansion of the elementary school curriculum beyond the 3 Rs, enforced since the 1862 Code, was easier in the 1870s when the Education Department gave grants, dependent on examination results, for passes in 'specific' and 'class' subjects. Specific subjects were introduced in 1871, whereby individual students in Standards IV to VI (ages 10 to 12) could be entered for not more than two subjects chosen from a given list, one of which was natural science. Even in the 1890s only about 2 per cent of children in elementary schools studied specific subjects, and, of these, only about 2 per cent studied chemistry and 10 per cent mechanics. Preference, it seems, was given to subjects requiring little specialized equipment or accommodation.

The syllabuses for the specific science subjects, particularly chemistry, were largely academic without much emphasis on everyday applications. The nature of the teaching expected is illustrated by this quotation from the 1882 Code

> It is intended that the instruction of scholars in science subjects . . . shall be given mainly by experiment and illustration. If these subjects are taught to children by definition and verbal description, instead of making them exercise their powers of observation, they will be worthless as means of education. It cannot, therefore, be too strongly impressed on teachers that nothing like rote learning will suffice (p. 30).

Class subjects were introduced in elementary schools in 1875 for Standards II to VI, making it possible for whole classes to be examined in not more than two listed subjects, grants depending on results. It was not until 1882 that elementary science became a class subject. Lack of equipment and suitably qualified teachers curtailed the growth of class and specific science subjects. The 1882 Code was significant in that it not only introduced elementary science but also indicated its scope. The Code defined elementary science as follows:

> A progressive course of simple lessons . . . adapted to cultivate habits of exact observation, statement and reasoning

and required that

> The class subjects should be taught by means of reading books and oral lessons, illustrated, as far as possible, by maps, diagrams, specimens and simple experiments (p. 26).

Thus much of the teaching, especially in Standards I to III, would be by means of descriptive, demonstration lessons, say, on a piece of coal, most likely in an ordinary classroom, with little participation by the children except for learning or writing factual material.

The striking thing about the elementary science syllabus for Standards I to III – common objects such as familiar animals, plants, and substances employed in ordinary life – is that it completely lacked purpose and system. Given teachers without much scientific training and inadequate equipment, repetition and superficiality were likely. A more advanced knowledge was required from Standards IV and V of further limited topics in biology, chemistry and mechanics, while Standards VI and VII dealt with these same topics in greater detail. Thus the work in Standards I to III would seem to provide a very poor basis for later studies in elementary science, and even worse for specific subjects. Elementary science was made a compulsory subject in 1896. Thus, for the first time, some science instruction was obligatory for all elementary school pupils.

More active participation by pupils was encouraged in the 1890s. The committee of the British Association for the Advancement of Science, which scrutinized elementary science teaching, emphasized in the 1891 Report (p. 385) that for pupils simply to 'exercise their powers of observation' was restricting, and that they should perform experiments themselves. 'Merely to attend lessons, listening to and taking notes of what is said,' it argued, was not enough.

A class subject of revolutionary design appeared in the 1894 Code. This was 'Experimental Arithmetic, Physics and Chemistry', which bore a resemblance to H. E. Armstrong's course (discussed below), and in which the teaching was to be experimental, with work done by pupils. Armstrong's influence can also be seen in the specific subject 'Elementary Physics and Chemistry' introduced in the 1898 Code. There is a reasonable blend of the two subjects in it, with a practical approach implied. This is the first Code science syllabus in which the word discovery appears – 'discovery of the active constituents of air' (p. 58).

By 1880, ten years after the Elementary Education Act was passed, some schools were faced with the problem of children who, having reached the statutory leaving age (12) and passed through all the Standards, were still attending school. The problem was overcome by the schools organizing science classes for their upper standards which led to

Science and Art Department examinations. Alternatively, higher grade schools were established, which took children from Standard V and upwards from nearby elementary schools. These courses, which bore no relationship to the Elementary Code, earned Science and Art Department grants for examination passes. Such arrangements, which allowed work of secondary character to be done in elementary schools, were winked at by the Education Department so long as some 'elementary' education as set out in the Code was done as well.

Most schools taking Science and Art Department examinations chose to take a few, not necessarily related, subjects, that is, to have science classes rather than become 'Organized Science Schools', where a three-year course of systematic instruction in related science subjects was provided. The Science and Art Department besides offering payment by results, also gave grants for equipment and laboratory furnishings. Indeed, it was financially advantageous for schools to take their examinations in preference to those offered in the Code.

The Science and Art Department's classes and examinations, which began in the 1850s and continued until the Department ceased to function in 1899, were originally intended for working people. Thus the syllabuses were unsuitable for children, as they were never intended for school use. It was 1896 before the Department introduced day examinations as well as those normally taken at night. In general, the Department's syllabuses were too academic for school use, while its examinations, being tests of largely factual material, encouraged rote learning and cramming. In some cases school curricula became over-biased to science because of their dependence on Science and Art Department grants. Nevertheless, the Department did encourage science teaching, and set standards for equipment and laboratories.

The Royal Commission on Secondary Education (1895) made a shrewd appraisal of contemporary science teaching

> the sciences are not mere catalogues of materials that can be used in trade, or abstract principles regulative of their economical use; they are systems or symbols of great ideas that may be used to exercise reason and fill the imagination. (Report, Vol. I, p. 141.)

As the nineteenth century progressed, the argument changed from 'Why teach science?' to 'How to teach science'. H. E. Armstrong, the eminent chemist, was instrumental in bringing about the formation of the British Association committee which inquired into the methods of teaching chemistry. The committee reported in 1888. From the response to a questionnaire which the committee sent to schools and training colleges, it was clear that most of the respondents considered the purpose of chemistry teaching was to give mental training and improve intellectual discipline. It was also clear that teachers wanted advice and assistance on how to teach. To supply this need, Armstrong produced a scheme of instruction.

This 'British Association Course' which Armstrong designed was in six stages; not only did it suggest content, but it also supplied a method and implied a reason for each stage. The course began with object lessons on the child's surroundings, drawing on a range of sciences, geography, geology, natural history, so that the 'variety of things' could be learnt and facility in description be developed. Stage II involved exercises in measuring length, area, mass, volume, density, for example, assuming proficiency in the 'four rules' of arithmetic and decimals. Having learnt to measure and weigh, the child was expected to be able to express differences in properties quantitatively. The third stage was concerned with the effect (both qualitative and quantitative) of heat on various elements and compounds. As a result of such experiments, it was thought, habits of correct observation and recording would be acquired, and the insight that chemical change was not simply destruction gained. Next came the problem stage, the most original and characteristic stage, with problems like 'What happens when iron rusts?'. There are thirteen of these and they were intended to show that to solve problems 'clues' must be sought. While the majority of pupils would not pass beyond this stage, there were two more. Quantitative determination of the composition of the compounds such as water and chalk was the basis of Stage V. Stage VI extended ideas on chemical theory. The course was novel in that it illustrated scientific method by emphasizing observation, reasoning from an hypothesis, and putting the pupils in the place of discoverers when they performed experiments chosen for the purpose. Thus, the course exemplified the heuristic approach.[3]

Despite its good intentions this course gained ground slowly. It was costly in time, it did not fit the existing examination syllabuses and it was too novel for many teachers to accept its challenge. However, the course (in a modified form) was used in some London Board Schools and elsewhere, largely by teachers who had been students of Armstrong. As has been described above, Armstrong's work led to changes in the Code, in examination syllabuses and in the greater emphasis placed on individual practical work. Armstrong's course was an attempt to interest children in a wide range of sciences and in the methods of scientific enquiry. There was, however, little consideration of modern scientific developments and their everyday applications. The value of a method had been emphasized to the detriment of interest.

The Board of Education's publications for science teachers in the early years of the twentieth century described the advantages which it was considered that younger children gained from studying science as learning to observe and learning by observing. With older children teachers were expected to place more emphasis on investigations by the children and to encourage careful recording and the drawing of correct inferences from their findings. Heuristic influences are seen here. By 1915, however, a Board of Education circular laid less emphasis on children's individual experiments. While the need for regular practical work was stressed, the use of demonstration experiments was also considered useful and encouraged. Already there seems to be a reaction against the excessive practical work allegedly engendered by heurism.

The Hadow Report (1926) *Education and the Adolescent*, argued that sound teaching should be based on the pupil's interest, suggesting cooperation between science and handwork departments to achieve this. The report considered science to be a unity, not a collection of separate subjects.

In the 1920s and 1930s the *Handbook of Suggestions* published by the Board of Education offered general guidance to teachers. Two aims for science teaching were given in the 1927 edition as awakening interest in plant and animal life and natural scenery, and the investigation of common phenomena and their underlying scientific principles. By following these aims, teachers, it was said, would be able to help children to understand the rules of health, the service of science to the community, and appreciate the beauties of nature. Although practical work in small groups was encouraged, the value of the demonstration experiment was stressed, since, 'in recent years its value has been too often forgotten' (p. 35).

Science in Senior Schools (Board of Education Pamphlet No. 89, 1932), gave the results of a survey by HMIs of 384 schools in England and Wales. It is plain from this document that the majority of boys' schools taught too much physics and chemistry and that girls' schools taught too much biology. *Science in Senior Schools* also contains a list of 'values' which the writers suggested should be gained from science courses. For instance, knowledge of scientific facts and principles should lead pupils to a more rational way of life, better health and happiness and to adopt useful hobbies. Science teaching, it was said, would develop an intellectual interest in the natural universe, as well as give some training in scientific method. The 'chief danger' in science work, the authors stated, was 'too much practical work of the wrong kind'. It was of the wrong kind if it was 'too remote from the natural interests and everyday experience of the children' (p. 14). Thus, courses which were too academic or too practical were not encouraged.

A new edition of the *Handbook of Suggestions* appeared in 1937. This handbook stressed that work for older pupils should be related to their 'immediate needs and interests', leading to self-education through books and a lasting desire to continue education after leaving school. Science teaching for senior children should help them to understand the methods of science, gain the 'scientific habit of mind', see interrelationships

among facts, and draw appropriate conclusions from evidence. These aims, which are more sophisticated than those in *Science in Senior Schools*, seem to some extent to lose sight of the abilities of many of the children concerned and the often inadequate facilities in these schools.

Public schools and grammar schools in the early twentieth century remained comparatively insulated from changing ideas on science education. There was some discovery teaching in the lower forms, but for the most part the curricula of both types of school were dominated by the requirements of the School Certificate examinations and later the General Certificate. No aims or objectives were suggested by Examination Boards for their examinations until the 1960s. Until this time, most of their science syllabuses were fairly academic, requiring little by way of applications. Question papers, in general, contained questions requiring factual or descriptive answers calling for little more than recall or comprehension.

In 1917 a British Association Committee chaired by Professor Gregory reported on science teaching in secondary schools. Its survey of science teaching showed that in both public schools and boys' grammar schools physics and chemistry dominated the science taught, though biology was becoming more popular. The opposite was the case in comparable girls' schools where mainly botany was taught. It is probably accurate to suppose that until the early 1940s, when general science gained in popularity, most of the pre-certificate science in these schools was taught as separate subjects.

The publication in 1916 of *Science for All*[4] by a group of public school science masters is important partly because of its content and partly because of its influence on later thinking. *Science for All* advocated a broad approach to science teaching, including work on plants, animals (not common at this time), as well as aspects of physics and chemistry. Contemporary applications were also a notable inclusion. The course was intended to capture the pupils' interest and to make science alive and personal for them. In effect, *Science for All* was advocating compulsory science, and a broad generalized science at that. Although it had little immediate impact on schools, its influence on later thinking was considerable.

The Gregory report of 1917, referred to above, encouraged the teaching of a wide selection of sciences in schools and also discouraged excessive practical work. The committee formulated the aims of science teaching at length, including among their aims training in observation and description, use of scientific method, gaining knowledge of the environment and man's relation to it, and acquaintance with current scientific words and ideas.

Yet another of the influences which encouraged general science was *Natural Science in Education*, published in 1918. This was the report of a committee set up by the Prime Minister, under the chairmanship of Sir J. J. Thomson, to advise, among other things, on what measures were needed to promote the study of natural science. (Other similar reports were commissioned on English, Modern Languages, and Classics.) The Thomson report favoured a science course for all boys and girls up to the age of 16. This course was to include, besides physics and chemistry, a study of plant and animal life, together with matters of everyday experience. The report defined the aims of science courses as giving students training in reasoning, interpreting evidence and acquainting them with scientific principles and their applications. While applauding practical work as a means of obtaining explanations of problems and giving experience of scientific method, the report was very scathing about heurism, and also considered that concentrating on those aspects of subjects which best lend themselves to practical work was unsatisfactory.

In the wake of these reports the Science Masters' Association published the pamphlet *General Science* in 1924 containing a syllabus in three sections, biology, chemistry and physics, fulfilling many of the recommendations of earlier reports. The Hadow Report (1926) on the education of the adolescent also contained a syllabus embracing biology, chemistry and physics as well as astronomy and meteorology. In 1936 the Science Masters' Association published *The Teaching of General Science Part I*. In this report general science was defined as a course of 'scientific study and investigation' based on the 'common experience of children', while not excluding 'any of the fundamental special sciences'. General science, it was said

> seeks to elucidate general principles . . . without emphasizing the traditional divisions into specialized subjects until such time as this is warranted by the increasing complexity of the field of investigation, by the developing unity of the separate parts of that field, and by the intellectual progress of the pupils (p. 30).

Thus, not only is an analytical definition given, but attention is drawn to the pupils' intellectual development. The aims of teaching general science were given as utilitarian, mind-sharpening, and cultural.

Part II of *The Teaching of General Science*, which appeared in 1938, contains a remarkable chapter on examinations. It is remarkable because it contains a list of what pupil abilities should be tested by examinations based on the proposed general science syllabus (set out in Part I and Part II). These abilities are given under four headings and can be summarized as follows: the first, acquisition of scientific information and knowledge, includes knowledge of facts and technical terms, as well as the ability to reproduce laws and principles and to explain their meaning. The next concerns development of scientific modes of thought, that is, ability to explain principles from facts and support principles with facts, to distinguish between fact and hypothesis, and to plan experiments and draw

conclusions. Application of scientific knowledge to socially desirable ends is the third set. Finally, there is a section on practical powers and skills, including such things as manual skill and dexterity, together with the ability to do neat, accurate work and to apply science to solve practical problems. (Illustrative questions were also given to show how some of these abilities and skills could be tested.) Although the writers of this chapter admit their debt to other authors, this list of abilities and skills is a landmark in thinking in this sphere in Britain, for not only are quite high level intellectual abilities specified, but practical skills as well. Implicit in all this is the idea that not only should examinations test such abilities, but teaching should encourage them. However, it was not until well after World War II, when emphasis on objectives, particularly in examinations involving objective questions, stimulated by Nuffield courses and some Examination Boards, that these ideas began significantly to influence school science teaching.

The Spens Report (1938) on secondary education contains a confused mixture of earlier ideas. It describes the aims of science teaching as giving pupils knowledge of natural laws operating in the universe and their applications, 'an appeal to wonder, interest, as well as utility', understanding of the influence of science, and an insight into 'scientific methods of thought and investigation'. The report rejected specialization in science before the age of sixteen, implicitly accepting general science. Echoing earlier reports, the Spens Committee repeat the claim that much laboratory work is a waste of time. The start of World War II in 1939 soon after these reports delayed any possible action.

The Norwood Report (1944) was concerned with secondary school curricula and examinations. Like the Spens Report it favoured general science below the sixth form, defining it in much the same terms as Spens, although admitting some pupils could study separate subject science after the age of thirteen.

An important book, *The Teaching of Science in Secondary Schools*, was published in 1947 by a joint committee of the Incorporated Association of Assistant Masters and the Science Masters' Association. (The outbreak of war prevented publication in 1939.) When discussing aims, the compilers, besides expecting a broad factual knowledge, stressed the value of accurate observation, good practical technique and critical assessment of experimental results. Adequate communication of ideas was considered important as was the appreciation of the connexion between science and everyday life, culture and human development. Although general science is admitted to be 'still in the experimental stage', its teaching is recommended, though allowing single subjects instead. The cramping influence of public examinations requiring memorizing of facts is lamented.

The years after the war were difficult because of shortage of teachers, equipment and accommodation. However, during the 1950s developments occurred some of them influenced by work in the USA which produced the Physical Science Study Committee materials, the Biological Sciences Curriculum Study, CHEM Study and other schemes.

The Science Masters' Association report *The Teaching of General Science* (1950) was a revised version of earlier reports (1936 and 1938). While embracing similar aims, it places more stress on practical work as enquiry.

Education through science was the keynote of *Secondary Modern Science Teaching* (Science Masters' Association, 1953). This report attached importance to arousing and maintaining pupils' interest. Besides gaining factual knowledge, it was thought that pupils should gain an appreciation of the 'scientific method of study'. Active experimenting was encouraged and there was a hint of the use of discovery methods.

A second revised edition of *The Teaching of Science in Secondary Schools* was produced in 1958. The aims do not differ greatly from those in the 1947 version, but the emphasis placed on adequate communication of results and unbiased judgement, whether in grammar or modern schools, is new. While the earlier version reviews research evidence regarding the relative merits of individual work or demonstrations, finding it inconclusive, the 1958 edition discusses the heuristic method, noting that the principle involved is widely used.

In a section dealing with the 11–15 age range, the Ministry of Education Pamphlet No. 38, *Science in Secondary Schools* (1960), suggests study of geology and astronomy as well as biology, chemistry and physics. The selection of topics for courses, it is said, should depend on their interest and importance to pupils. The two major aims of science courses are given as acquisition of knowledge and development of objective thinking. In addition, the 'spirit of investigation', gained through first hand experimenting, is to be cultivated, as is an understanding of scientific method. Improvement of self-expression and careful reasoning is also recommended.

Policy statements of major importance appeared in 1957 and 1961 entitled *Science and Education*. (The former was compiled by a committee of the Science Masters' Association, the latter by a joint committee of the SMA and the Association of Women Science Teachers.) The 1957 statement was concerned mainly with grammar school children. By the O-level stage, the report considered that children should have a basis of scientific facts and principles 'rooted firmly in practical experience'. Practical work was seen as a means of solving problems and instilling good technique. An understanding of the methods of science was also expected. The 1961 statement is very similar, but makes specific reference to the relationship between science and technology and its implications for schools not found in the earlier version. Likewise, the desirability of

children in the 13–16 age group having a 'reasonable amount of factual knowledge', (p. 9) and more quantitative and systematic work appears only in the 1961 version. In justifying the place of science in the curriculum the humanity of science is stressed in both statements.

Biology for Grammar Schools, with booklets of similar titles for chemistry and physics, were published by the SMA and AWST in 1961. These booklets which were based on the principles set out in *Science and Education*, offered up-dated syllabuses with suggestions on how to teach them. They had considerable influence on the early Nuffield science projects.

One of the highlights of the 1960s was the devising of the Nuffield biology, chemistry and physics O-level projects, having aims reflecting those in *Science and Education*. The aims of these three projects differ in detail, but two major ideas stand out. First, underlying principles are stressed; understanding principles is considered to be more important than just learning facts. Related to this is the ability to distinguish between facts, generalizations and hypotheses. Secondly, the discovery approach to practical work is prominent, with the intention that, where possible, principles should be established through practical work. In addition to acquiring manipulative skills and accuracy in observation, opportunities to plan experiments are recommended so that pupils may appreciate the limitations of experiments and the value of the data they collect. In brief, to 'encourage enquiry' and 'develop curiosity'. In all three schemes the content is up-dated and includes consideration of the relation between science and the community. Special examination papers from these Nuffield courses, based on their specified objectives, were also introduced.

Science for General Education (the Scottish Education Department's Curriculum Paper No. 7, 1969) has had considerable influence in Scotland and elsewhere. Detailed objectives are given for the first two years of secondary education (12–14 age group in Scotland) and also pupils who will not stay in school after the statutory leaving age. These objectives are derived from general aims including problem-solving, scientific thinking and the cultural value of science. Thus as well as factual knowledge, comprehension, application and synthesis are expected. The content which includes biology, chemistry and physics (integrated where appropriate), is selected to stimulate pupils' interest and enjoyment. Good communication of ideas is encouraged and discovery methods are used in practical work.

The increase in the number of comprehensive schools in England and Wales, and classes having wide ability range led to the development of a combined science course. The Nuffield *Combined Science* materials for the 11–13 age group were published in 1970. The course materials were selected from appropriate parts of the three O-level courses, giving an introductory science course involving pupils in active enquiry. Thus, *Combined Science* shared a similar approach and similar aims as the O-level schemes, but was intended for able and less-able pupils, who, it was hoped, will learn how the various sciences interrelate and gain a 'unity of outlook and consistency of method which belong to the whole of Science' (*Teachers' Guide I*, p. xi).

Another set of combined science materials was published in 1970. This was Nuffield *Secondary Science*, designed for 13–16-year-olds not taking GCE O-level. It differs from *Combined Science* in using a thematic approach. Teachers are intended to plan their courses by selecting material from the eight themes to give pupils a broad background of science, related to their interests, needs and future employment. Pupils are encouraged to plan their own experiments (some involving care of animals and plants), and to be accurate when making observations. They are also expected to gain understanding of generalizations and hypotheses as well as improving literacy and numeracy. The choice of content for the eight themes was governed by the criterion of 'significance', that is the underlying interest and relevance to pupils' experience, in and outside of school, as well as illustrating basic scientific principles. Besides dealing with applications of science, the course touches on moral and social problems.

Of all the recent science projects perhaps the most unusual in content and approach is the *Schools Council Integrated Science Project* (1973). While not using a thematic approach, it draws together biology, chemistry and physics as well as earth sciences and the social sciences. There is considerable emphasis on 'relevance', which in this context means not only the applications of science to technology but also the importance of science in society. SCISP is for the 13–16 age group of O-level ability. 'Patterns', that is generalizations, figure prominently in SCISP materials. Apart from acquiring factual knowledge and understanding patterns, pupils are expected to view evidence critically, use reasoned judgements in problem solving, design experiments, and communicate their findings. Pupils are also expected to develop attitudes such as working alone or in groups, appreciating the scope and shortcomings of science, and caring about the implications to mankind of the applications of science.

The change in emphasis in these projects towards integrated science with increasing reference to social and technological problems arises in part from attempts to combat the worsening popular image of science. A similar change of emphasis can be seen in the ASE publications of this period.

School Science and General Education, the ASE policy statement issued in 1965, does not differ greatly from the 1961 policy statement. However, the 1965 version emphasizes that it is addressed to all schools, not just grammar schools. This was followed in 1967 by *Science in the Introductory Phase* (the 11–13 age group). Three integrated science courses are offered, based on the ideas in *School Science and General Education* (1965). These three courses, it was hoped, would provide material for the growing number of schools teaching integrated science at this level. The courses were designed to develop a scientific attitude using an investigatory approach, at the same time encouraging interest and enthusiasm.

A revised version of *Secondary Modern Science Teaching* appeared in 1967 entitled *Teaching Science at the Secondary Stage*. This book was prepared by an ASE committee for teachers of 'average' pupils. It suggests that science courses should be based on pupils' day-to-day experience. It also recommends that modern applications should be used as starting points for teaching to encourage interest. There is an emphasis on discovery practical work, whether demonstration or individual. Skill in use of apparatus and equipment is encouraged, as is a critical approach to evidence.

The third revised edition of *The Teaching of Science in Secondary Schools*, devised by a committee of the ASE, the Assistant Masters' Association and the Association of Assistant Mistresses, was published in 1970. This book is now addressed to teachers in all types of school. After dealing with several misconceptions of what science is, the importance of science as a 'major human activity' is discussed. The aims of science teaching are discussed in general terms, reference being made to acquiring factual knowledge as a means of acquiring appropriate intellectual abilities and skills, including applying knowledge to solving unfamiliar problems. Manipulative skills are also considered important. The aims of the Nuffield O-level chemistry course are quoted as being generally appropriate for science teaching.

Finally, the recent ASE policy statements must be considered. *Science and General Education* (1971) takes into account the increased complexity of school organization and the growing use of mixed-ability classes. Science teaching, the statement argues, should illustrate the effect of science on modern life and social organization. It should also show that science demands 'creative insight and imagination' to counter current misconceptions of science. Teachers choosing course materials should remember the children's needs, the relevance and social implications of topics. In a section on the future, the 'laboured insistence' of recent curriculum developments on discovering concepts and principles is noted, with the hope that besides discovering principles, opportunities will be taken of 'creatively following up the implications of principles' in applied science and technology (p. 8).

Science and General Education was followed by *Science for the Under-Thirteens* (1971). This report suggests objectives which would help pupils to 'gain experience and acquire techniques appropriate to their personal abilities', which would fit them for future courses at the 13–16 stage.

Science for the 13–16 Age Group (another ASE report published in 1973) describes the scope of science for this age group in three sections. This is an attempt 'to achieve a balance between three aspects of science education'. The first section on basic principles is called 'Science for the Inquiring Mind'. Then comes 'Science in Action', suggesting pupils should have 'a basic knowledge of themselves, their physical and biological environments and the interrelationships between them'. Thirdly, 'Science for Citizenship' concerns knowledge needed for making personal and collective decisions. The purpose of courses based on these principles is specified by means of a list of aims for teachers. Included in this list are relating science to life, developing manipulative skills and caring for things, teaching for understanding rather than recall, the methods of science, encouraging communication, imagination, and inventiveness, as well as providing training for decision-making. Science is to be seen, the report states, as a human activity 'offering both promise and threat' (p. 8).

Having surveyed the changes in the aims of science teaching, and briefly sketched in some of the influences responsible for change, a number of important points stand out. The last twenty years have seen the most rapid and radical changes in science curricula and the approach to science teaching. Views on the nature and purpose of practical work have swung back and forth over the years, though ideas on what the teaching of science involves have grown, ranging from a factual knowledge of single subjects to an understanding of aspects of several sciences, together with related moral and social issues. The intellectual demands of what is taught have increased from rote learning in the nineteenth century to the sophisticated abilities and attitudes expected in recent years. Factors influencing change are difficult to quantify, often resulting from the aspirations or constraints of the times. However, with a background of these various changes, it is possible to consider current and future developments in science education in a truer perspective.

NOTES AND REFERENCES

1. See, for example, Layton, D., *Science for the People* (George Allen and Unwin, 1973).
2. Wilson's essay appears in Farrar, F. W., *ed.*, *Essays on Liberal Education* (Macmillan, 1867).
3. There is much background material in Brock, W. H., *ed.*, *H. E. Armstrong and the Teaching of Science* (Cambridge University Press, 1973) and Armstrong, H. E., *The Teaching of Scientific Method* (Macmillan, 1903).
4. Reprinted in *School Science Review* 1926, 6, 2, 203.

16 Why the science curriculum changes — evolution or social control?

● D. Hodson and R. B. Prophet

Hodson and Prophet seek to provide an explanation of the shifts in the aims and practice of school science detailed by Uzzell (Chapter 15). They suggest that social Darwinist explanations, emphasizing the failure of certain modes of teaching, are inadequate: it is more pertinent to examine the interests of those who control the curriculum in order to explain the abandonment of certain practices. Although they reject the idea that all knowledge is socially constructed, they use the theoretical framework of the 'new sociologists' to show that school science is so constructed in that it is the product of particular sets of choices made by particular groups of people at particular times.

Peter Uzzell[1] has traced the changing aims of science education from the early days of school science in the nineteenth century through to the Nuffield projects of the 1960s and the more recent Schools Council project in integrated science (SCISP). What is absent from this admirable article and from other works dealing with the history and development of the science curriculum (such as Jenkins[2], Layton[3] and Turner[4]) is any convincing account of *why* the curriculum changed in the particular way that it did. In a later article exploring the changing status of science in the curriculum as reflected in official reports, Uzzell concludes:

> . . . What is taught, the manner of teaching and the resources for teaching are of crucial importance, as are the needs of children and our country. *Who will decide and on what grounds?*[5] (our italics)

This chapter speculates on these questions by taking a historical perspective, in the belief that some light may be shed on the question 'Who *will* decide curriculum issues?' by attempting to ascertain who decided