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ABSTRACT

British science curriculum improvement projects on the elementary and secondary school levels are reviewed in this volume to indicate their implications for the development of second-generation programs in the United States. Included in the British second-generation program category are: the Scottish integrated courses, Nuffield combined science, Nuffield secondary science, and the Schools Council integrated science project. Detailed descriptions are given to these more-or-less unified programs in terms of course objectives, course construction principles, teaching techniques, materials available, and current status. To provide perspective, a brief summary is also made of other British projects: Nuffield O level schemes, Nuffield A level science project, Science 5/13 (for 5- to 13-year-olds), Nuffield Junior Science Project, Scottish science, Schools Council Project Technology, and Biology for the Individual. Differences between curriculum projects in Britain and the United States are examined in terms of project initiation, program flexibility, and financial support. Also included is a bibliography of publications referred to in the projects, with publishers' addresses incorporated at the end. (CC)

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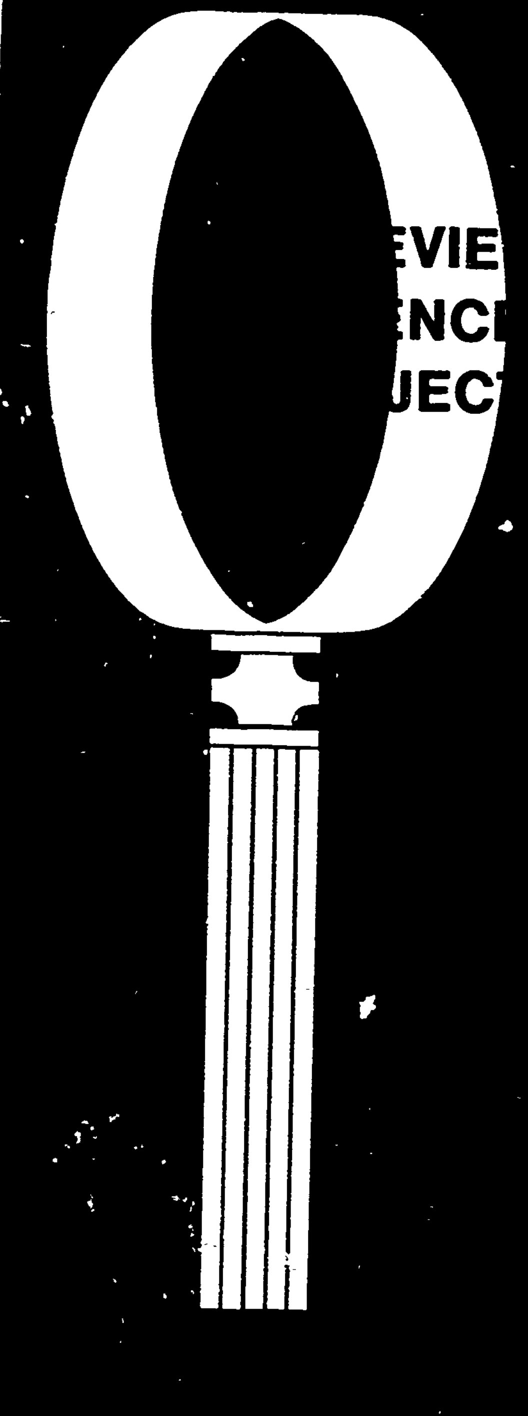

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SCIENCE EDUCATION INFORMATION REPORTS

A REVIEW OF BRITISH SCIENCE CURRICULUM PROJECTS

Implications for Curriculum Developers

by
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SCIENCE EDUCATION INFORMATION REPORTS

The Science Education Information Reports are being developed to disseminate information concerning documents analyzed at the ERIC Center for Science, Mathematics and Environmental Education. The Reports include five types of publications. *General Bibliographies* are being issued to announce most documents processed by the Center for Science, Mathematics and Environmental Education. These bibliographies are categorized by topics and indicate the availability of the document and the major ideas included in the document. *Special Bibliographies* are being developed to announce availability of documents in selected interest areas. These bibliographies will list most significant documents that have been published in the interest area. *Guides to Resource Literature for Science Education* are bibliographies that identify references for the professional growth of teachers at all levels. *Occasional Papers* will be issued periodically to indicate implications of research for the teaching of science education. *Research Reviews* will be issued to analyze and synthesize research related to science education over a period of several years.

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SCIENCE EDUCATION INFORMATION REPORTS

Science Education Information Reports are being issued to analyze and summarize information related to the teaching and learning of science education. It is hoped that these reviews will provide information for development personnel, ideas for teachers, and an indication of trends in education in science education.

Your comments and suggestions for this series are invited.

ROBERT W. HOWE
Director
ERIC/SMEAC

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PREFACE

There is a world-wide interest in curriculum renewal. There are curriculum development groups in most countries of the developed world; among the developing nations local and regional curricula are being developed, often under the auspices of an international or bilateral agency, or foreign materials are being translated or adapted. At this time, therefore, it is advantageous to have available interpretative descriptions of existing developments, both as a record of current interests and as a source of ideas for workers in other countries.

It is not only the emerging nations that can benefit from descriptions of curriculum programs in the developed regions. No one developed nation has a monopoly on the ideal method of curriculum development; there are differences in assumptions and educational settings even between countries with a common background and language. These assumptions, which are often implicit and therefore unquestioned, can be recognized when a comparison of trends and practices is made. By such comparisons, therefore, alternate successful procedures can be recognized, assumptions can begin to be questioned, and a cross-fertilization of ideas established.

This report of recent British science curriculum developments, concentrating on those that have produced materials for secondary school science courses that integrate the special sciences, is addressed primarily to American science educators. However, the descriptions of the programs and the analysis of trends, including the comparisons with American science course improvement projects, should make the volume useful to educators in other regions of the world. It is the first of a series of such comparative studies.

The cooperation of Hilda Misselbrook, M. J. Elwell, W. C. Hall, and A. W. Jeffrey, with whom one of the authors discussed Nuffield Secondary Science, Nuffield Combined Science, Schools Council Integrated Science Project, and Scottish Integrated Science, respectively, is greatly appreciated, not only for the information that they provided about their programs, but also for making it possible to meet teachers and students using the materials their project had produced. J. R. Barr, Science Adviser, Edinburgh Education Authority, spent much time arranging visits to representative schools and the Teachers' Centre in Edinburgh. We are also indebted to the staff and students in the schools visited for their helpful comments and tolerance of a stranger in their classroom.

Although these persons provided much information about the programs discussed they are not responsible for the selection of the illustrative examples used or for the interpretations made.

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Visits to the curriculum development projects, schools and educational institutions in Britain (arranged by the Centre for Educational Development Overseas, London), and the preparation of the report were supported by the ERIC Analysis Center for Science, Mathematics, and Environmental Education and by the Center for Science and Mathematics Education, the Ohio State University. The work was undertaken while A. M. Lucas was a recipient of a Fullbright-Hays Travel Grant from the Australian-American Educational Foundation.

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1

INTRODUCTION

At the beginning of the seventies science educators in the United States appear to be searching for methods to satisfy demands that are not being met by the extensive curriculum developments of the past decade. An increasing number of school systems are introducing some form of secondary school science teaching that dispenses with traditional subject boundaries. In 1966, when the Federation for Unified Science Education (FUSE) was formed, there were eight such programs known. In 1972 FUSE includes in its membership about 150 schools teaching or planning some form of unified science course.

Authoritative statements in the science education press also advocate change in the directions of science education. Hurd [1], for example, discusses the priorities for science education that he sees emerging to replace the earlier dominant concern for "developing courses to reflect the modern theoretical structure of particular disciplines and their rational processes." [2] He suggests that science education now needs to

a) be related to national goals,
b) take note of technological achievement and its interaction with society,
c) be taught in a social context,
d) lead to the formation of values which "may serve to convert knowledge into wisdom and make for responsible social action," [3]
e) prepare students for a world of change,
f) permit the pupil to "free himself of the present and . . . consider ways in which a more satisfying future for mankind might be planned," [4]
g) emphasize the use of knowledge to solve social problems, and
h) "integrate knowledge and interrelate modes of knowing." [5]

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Hurd's priorities are compatible with the characteristics of new high school programs desired by the participants in the 1971 National Science Foundation Callaway Gardens conference of scientists and science educators. [6] In their view, future science programs in the United States should be characterized by

a) being completely unified and suitable for all students,
b) prespecified minimal levels of scientific literacy for which instructional and evaluative components are available,
c) flexibility of goals beyond the basic minimum,
d) short units which can be flexibly arranged to suit individual students,
e) a balanced interdisciplinary coverage of the basic and applied sciences, including social sciences and engineering,
f) relatively independent units,
g) multiple pathways for achieving specific goals,
h) units compatible with individual, self-paced study,
i) utilization of existing resources to prevent instructional costs from exceeding present levels, and
j) specific suggestions for (i) alternate possible pathways through the units produced
(ii) organization and management of laboratory and other aids, and
(iii) assessing, and reporting, student progress. [7]

The Conference participants felt that one of the factors contributing to present problems was the ubiquitous United States high school science-course sequence of biology-chemistry-physics. As a consequence of this traditional arrangement, the products of the first generation science course improvement projects for high schools are predominantly arranged in year-long, single-subject units, thus severely limiting the options open to science departments attempting to use modern curricula to free courses from the prevailing rigid pattern. The Conference recommended that, as part of any new science curriculum development, the historical sequence be questioned. [8]

These examples of change and the advocacy of change suggest that a unified approach to the sciences in their social setting, perhaps including a study of the social as well as the natural sciences, is evolving in the United States. Provision of materials facilitating the development of the courses needed will not be a simple matter of adapting the existing highly-sequenced, monolithic programs. As Burkman points out, "although the experience that has been gained [from the first generation projects] could result in a number of efficiencies in future efforts, the extent of these should not be overemphasized." (9)

British science education has a number of features that imply that United States developers of second generation projects may be helped in their planning by an examination of recent British materials. British secondary schools do not have a tradition of sequential science courses. There have been science curriculum improvement projects active since the early 1960's. Second generation projects, emphasizing the unity of the scientific approach and considering social, moral and technological interactions with the scientists' work, are now available or are in the trial stages. Even though the use of local examples of the interactions of science and society would inhibit unmodified adoption of foreign programs in the United States, they do provide models for unified, open-sided, open-ended science courses. ("Open-sided" is used here by analogy with the common usage of open-ended—an extended scientific study not limited by prescribed course content. Open-sided implies a course which encourages students to freely explore the interactions of "scientific" topics with areas outside the traditional bounds of science. Moral, economic, political, social, and aesthetic aspects of scientific developments are among the possible areas which may be considered.)

Four programs, (Scottish Integrated Science, Nuffield *Combined Science,* Nuffield *Secondary Science,* and the Schools Council Integrated Science Project) are described in detail in Chapters 4-7. Although all are more-or-less unified in their approach they provide a range of possible curriculum models. There is variation in the degree of flexibility built into their materials, the rationale for the choice of content, the type of published material, and the age and ability range of the intended audience.

The descriptions are based on the published materials, with some supplementary comments based upon discussions with the project directors, teachers at an inservice conference, and teachers and students in schools in the London and Edinburgh regions. Anecdotes included are designed to serve as illustrations of the way in which the programs are being used in some schools. There are insufficient data supplied for this report to be used to infer generalizations concerning current science teaching techniques in English and Scottish schools. The materials and objectives of the programs are described; they are not evaluated in terms of their success in British schools. Excerpts from the materials are used to demonstrate some of the flavor of the originals: in this way it is hoped that a more adequate impression of the materials can be given to the reader.

A brief description of the British educational systems, an account of the development of science education in the schools, and descriptions of the other science curriculum improvement projects undertaken in Britain are included to enable the four second generation projects to be seen in perspective. These summaries include the programs developed for elementary and middle schools.

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2

THE BRITISH EDUCATIONAL SYSTEM

Local Responsibility

Education in the United Kingdom is essentially decentralized with much autonomy in the hands of Local Education Authorities and individual schools. These Local Education Authorities (LEAs), of which there are more than 150 in England and Wales alone, comprise the counties (for example: Yorkshire, Lancashire) as well as the large towns called County Boroughs (for example: Birmingham, Manchester and Leeds, as well as London which is the largest of the LEAs). Plans for the re-organization of local government have been prepared which, when implemented, will reduce the number of LEAs to about 100.

There is a national Ministry of Education, called the Department of Education and Science (DES), controlled by a Secretary of State who is the senior politician at the head of the department and a member of the Government of the day. The Secretary of State is assisted by two Parliamentary Under-Secretaries of State. The DES is staffed by permanent civil servants whose appointments do not depend on political considerations.

Scotland and Northern Ireland each has considerable autonomy and there are separate Education Departments, established by Parliament, responsible for the two separate systems, but there are still Local Education Authorities with autonomy as far as most educational matters are concerned.

The central government does not operate any schools or colleges, or engage any teachers, or prescribe any textbooks or curricula, but it does

a) set minimum standards for provision of educational facilities
b) control the rate, distribution, nature and cost of educational building
c) control the training, supply and distribution of teachers and determine the principles governing recognition of teachers as qualified
d) administer a pension or superannuation scheme for teachers

e) determine the size of the Treasury grant to be allocated to local authorities in the light of forecasts of local authority expenditure on education

f) support financially by direct grant a limited number of institutions of a special kind ('direct grant' schools)

g) support educational research through the National Foundation for Educational Research, university departments, and other organizations

h) settle disputes, for example, between a parent and a local education authority or between a local education authority and the governors of a school.

i) appoint Her Majesty's Inspectors (HMIs)—see below.

Responsibility for providing education (other than in universities) rests with the Local Education Authorities. These are the elected councils of counties and county boroughs. The councils appoint education committees, comprising some of their own elected members together with some persons with experience in education and knowledge of local educational conditions. The LEAs build schools, employ teachers, appoint local inspectors or school supervisors (who are in addition to Her Majesty's Inspectors) and provide equipment and materials. It is their duty to ensure that there is efficient education at all levels to meet the needs of the population within their areas. What is actually taught in each school is normally decided on behalf of the LEAs by the individual staff of the school concerned.

Education is by far the largest service provided by the locally elected councils. The cost is met from rates (a local property tax) and from a grant from the central government (Rate Support Grant). In 1972-73 the total of central assistance to local authorities in aid of all services provided (including education) is about 58 percent of their expenditure.

Every state primary school has a body of managers and every secondary school a body of governors. The general running of the school—curriculum and day-to-day conduct—is the responsibility of the managers or governors in consultation with the head teacher or principal, who is usually vested with rules or articles of government which effectively give him control over organization, discipline and curriculum.

The Inspectorate

Although the Secretary of State for Education and the Department of Education and Science have no direct control over the curriculum, they can exercise an advisory role, notably through the central Inspectorate. The primary function of the Inspectorate is, broadly, to report to the Secretary of State on education in the schools and colleges. All schools, of whatever kind, are open to inspection. HM Inspectors also offer advice to local education authorities, colleges and schools and discuss day-to-day problems with them. The Inspectorate gives professional educational advice to the Department of Education, provides a focus for educational development, conducts courses for serving teachers and prepares advisory publications.

There are about 500 HM Inspectors. There is a senior chief inspector and six chief inspectors, three concerned mainly with the work of schools, two concerned with further education and one concerned with the training of teachers. Some 60 staff inspectors are responsible on a national basis for particular subjects such as English, science, mathematics, or for particular sectors of education e.g. primary schools, training of teachers. The country is divided into regions each with a divisional inspector.

The Inspectors are usually recruited from experienced teachers and others with direct educational expertise.

The Structure of Education

Since the 1944 Education Act, State education in the United Kingdom has been divided into primary and secondary levels with a normal age of transfer at 11-12 years (Grades 6 or 7). Following the 1944 Act the educational system at the secondary level was based on a tripartite arrangement whereby children transferred at the age of 11 (Grade 6) to either a secondary grammar school offering a relatively academic education for approximately 25 percent of the age group, a secondary technical school offering some form of vocational training, or a secondary modern school for the large majority. Very shortly after 1944 there were moves in various parts of the country to provide bilateral type of schools combining, for instance, secondary grammar and secondary technical or secondary technical and secondary modern type of education and even in the 1940's there were a few multi-lateral or comprehensive schools. During the 1950's and 1960's a trend towards comprehensive type of education (general high school) accelerated and, at one stage, it became official government policy even though the transition depended on the agreement of the individual LEAs. The present position is that a majority of LEAs have decided to adopt some form of comprehensive education whereby children at the age of 11 or 12 (Grade 6 or 7) transfer to a secondary comprehensive or high school. Consequently the selection procedure, based on the infamous 11 plus (Grade 6) examination, has largely disappeared. There are however, some parts of the United Kingdom in which secondary grammar schools still exist and for which a form of selection, but not often a single 11 plus examination, is in being. More recently still, there is a move in some parts of the country to introduce middle schools or junior high schools with an age of transfer at about 9 years (Grade 4) offering a four year education in Grades 5-8. Apart from such developments, primary education in England and Wales ranges from the age of 5 to 11 (Grades 1-6) and is often divided into an infant's stage (Grades 1-3) followed by a junior stage (Grades 3-6). In some areas there is kindergarten or nursery education from the age of 3 or 4 years. [In Scotland the age of transfer from primary to secondary education is usually 12 years (Grade 7).]

There are about 25,000 primary schools, of which about half offer the complete range from grades 1 to 6 (7 in Scotland). About one fourth take infants only (Grades 1 and 2); most of the rest take juniors only. The great majority of the primary schools take both boys and girls. About half the primary schools have between 100 and 300 children each: most of the rest are smaller. About 35-40 percent of the primary schools are "voluntary-aided" schools. This means that they were originally established by a voluntary agency, usually the church, and, although still linked with that agency, now receive considerable financial support from the local education authority.

Throughout the United Kingdom there is approximately one secondary school for every four primary schools i.e. there are about 5,500-6,000 secondary schools. Over half of them take between 300 and 600 pupils each. Many of the former grammar schools offer separate education for boys and girls but the majority of secondary schools are now coeducational.

Compulsory education lasts, at the present time, from the age of five to fifteen but it is to be extended to the age of 16 during 1972/73. Already a large proportion of students stay to the age of 16 (Grade 11) or later on a voluntary basis but there are regional variations within the country and there are also differences between boys and girls schools.

Superimposed on the state system of education there is the private system, part of which is traditionally known as the "public school" sector. This sector includes famous schools such as Eton College, Harrow, Winchester, Charterhouse etc., but there are many others of lesser fame. There are about 3,000 non-maintained fee-charging schools, the majority of which receive no grants from public funds. All independent schools, however, have to be officially registered and open to inspection. Those which achieve the required standard can be recognized as "efficient" by the Secretary of State and about half come into this category. Of the 3,000 or so fee-charging schools about 200 receive a grant directly from the central government and are known as "direct grant" schools. These schools take some students who are paid for by the local education authority in addition to those whose fees are paid partly or wholly by parents. Figure 2-1, page 10, illustrates schematically the educational structure in England and Wales.

Many of the independent or direct grant schools offer primary or preparatory education. The independent secondary schools, often boarding schools, have by tradition admitted students at the age of 13 (grade 8).

Examinations

At the secondary level in England, Wales, and Northern Ireland there are two main public examinations—the General Certificate of Education and the Certificate of Secondary Education (GCE and CSE). There is a separate Scottish Certificate of Education.

The examinations for the General Certificate of Education (GCE) were introduced in 1951 to replace the former Schools Certificate and Higher School Certificate examinations. The GCE is granted by eight separate examining bodies in England and Wales, most of them connected with a University. The GCE provides a convenient indication of minimum qualifications for entrance to higher education. It is also accepted by many professional bodies as equivalent to their preliminary examinations. A candidate for the GCE may take as many or as few subjects as he wishes. Subjects are offered at two levels—the Ordinary and the Advanced level. The Ordinary level papers are normally taken at the end of the five year secondary course i.e. by students at the age of about 16 (Grade 11). The Advanced level papers are taken normally two years (Grade 13) later following a "sixth form" course of study. The GCE Ordinary level is taken by about 20-25 percent of the age population, that is by the top academic quartile of the student population. The Advanced level GCE is taken by a smaller proportion still—perhaps 10 percent. Advanced level passes in two or more subjects are the normal entrance requirements for Universities.

The Certificate of Secondary Education (CSE) was introduced in 1965. It is intended for those children of average ability for their age group. The examination can be taken by students after completing five years of secondary education (Grade 11) and any number of subjects can be offered. The CSE is controlled largely by teachers serving on committees in one of the fourteen regional boards.

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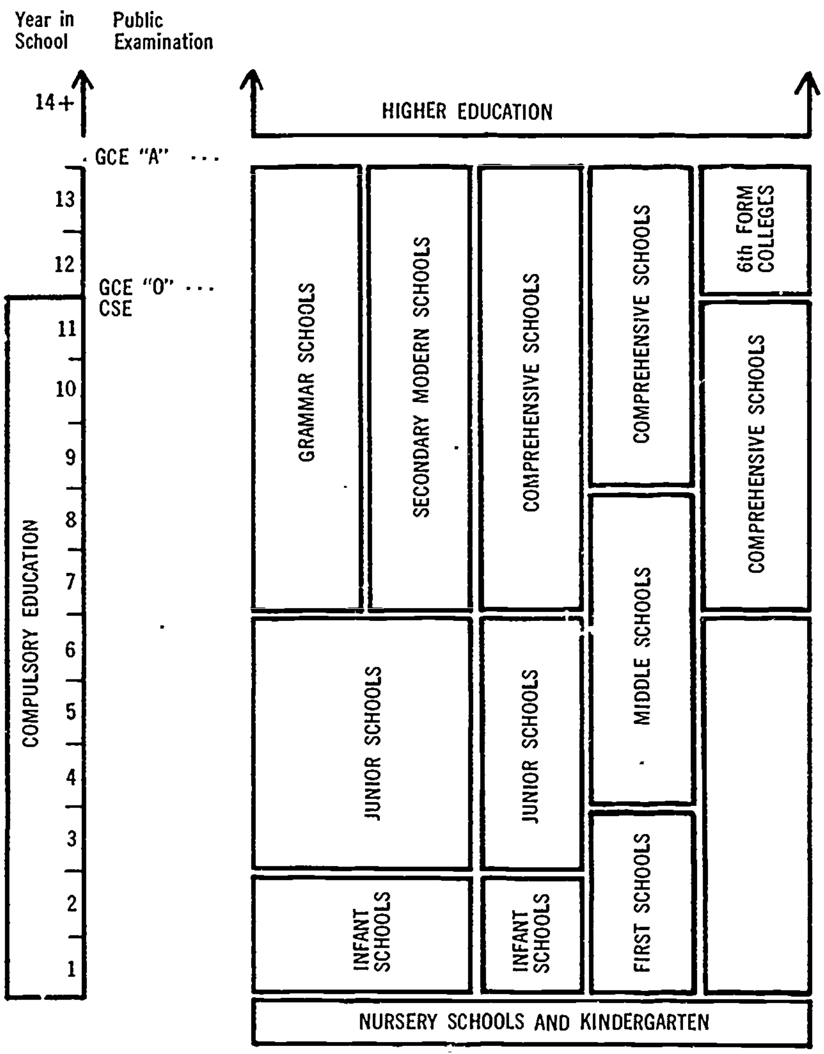
FIGURE 2.1

Schematic diagram of the structure of education in England and Wales

Not all arrangements that exist in British LEAs are shown in the figure. Some regions have secondary technical schools; and in some the age of transfer to and from middle schools differs from that shown here.



In Scotland the Scottish Certificate of Education Ordinary Grade is taken after four years of secondary education (Grade 11) with the Higher Grade taken one year later (Grade 12) and a relatively new Certificate of Sixth Year Studies available a year later still (Grade 13). The Higher Grade Scottish Certificate of Education if obtained in the appropriate subjects will admit to Scottish Universities, which traditionally have offered four year courses to a first degree (B.Sc., for instance). The university courses of English and Welsh universities are normally of three year duration to first degree level from the entrance standard of GCE Advanced level.

Although there is no direct central control of curricula in schools the existence of the public examination system means that there are clearly defined syllabuses in the various subjects, and at the various levels, which naturally provide a definite guide to teachers and students in preparing for these important school leaving examinations.

Modern developments in curriculum reform have been reflected by the Examination Boards in the offering of a variety of alternative syllabuses. In the CSE for instance, there is provision for an individual teacher to prepare his own syllabus and scheme of work, to write his own question papers, and to mark the candidates' papers. This flexibility in a secondary school leaving examination represents a major change from the domination of school curricula by external examinations.

Teachers and Their Training

Teachers in state schools must be qualified. To become a "qualified teacher" in England it is necessary to have successfully completed an initial course of teacher training—normally of three years duration at a college of education. There are 160 such colleges. Qualified teacher status is also given to university graduates or to persons with certain advanced qualifications of professional bodies. After 1973 it will be necessary for graduates to complete a one year postgraduate course of professional training before they can be recognized as qualified teachers. At present such postgraduate courses are optional but many graduates do in fact choose to undertake this professional training before entering the teaching profession. In Scotland professional training is compulsory and all Scottish secondary school teachers are university graduates.

All qualified teachers in state schools are required to serve a probationary period to satisfy the authorities of their practical proficiency.

3

SCIENCE EDUCATION IN BRITISH SCHOOLS

Historical Development

There is a relatively long tradition of science teaching in British schools. Science was first introduced into the curriculum of the "public" (i.e., private) schools prior to 1900 and it extended into the state schools on a considerable scale during the period between the two World Wars. Much of the initiative for the original introduction of science and for its extension was in the hands of science teachers themselves who established the Science Masters' Association more than half a century ago. This was followed by the establishment of an Association for Women Science Teachers and both organizations grew rapidly in size and strength. The two organizations merged into the Association for Science Education (ASE) in 1961. The activities of the ASE now extend into primary schools as well as to Colleges of Education and other establishments of higher education. The membership of the ASE is approximately 14,000 and their journal, the *School Science Review,* is widely read both in Britain and overseas.

During the 1930's the Science Masters' Association developed schemes for teaching general science in secondary schools. These unfortunately were never entirely successful although some schools still offer general science as a GCE subject at Ordinary level. Such general science courses were, and still are, co-ordinated surveys of physics, chemistry and biology. Only rarely is there real unity in presentation of the courses. In some cases an attempt at unity is made through a "topic" approach but, with notable exceptions, teachers have failed to achieve any real integration in their teaching. The original general science schemes, as well as those still perpetuated on the old syllabuses today were regarded as an inadequate base from which to develop more advanced science courses (e.g. at GCE Advanced level), being too superficial and lacking in quantitative study. Moreover, head teachers often allocated a smaller proportion of time to general science than to the separate sciences and thus general science became a course suitable for the less academic. The more academically inclined students, however, have always offered separate sciences at the GCE examination although it is quite usual for girls to offer biology and for the boys to offer either physics separately from chemistry or perhaps a physics with chemistry special paper at the Ordinary level.

The syllabuses for the sciences became more and more factual and more and more crowded during the period 1945-1960. So much so that the Science Masters' Association and the Association of Women Science Teachers established a number of Subject Committees during the 1950's and made an attempt to revise considerably the existing traditional science syllabuses. Their efforts were published in the period 1957-1961 as a series of leaflets dealing with new syllabuses and explanatory notes[1]. The Science Masters' Association also published a policy statement advocating the introduction of science as part of general education for *all* pupils in the first five years of secondary education.[2] This was to counteract a tendency for many schools to allow specialization between Arts and Science to begin at the 3rd or 4th form (Grades 9, 10) of the secondary schools (i.e. at the ages of 14 or 15). It has been traditional in Britain for specialization to begin at the 6th form (Grade 12) level (i.e. the age of about 16-17) when students would normally select a group of subjects, either on the science or the arts side. Even at this level however, there are moves towards more general education, but the pressures from the Universities still make it usual for students to specialize in either the science or arts stream.

Modern Curriculum Projects

The syllabuses and policy statement published by the SMA and AWST in 1959-1960[3] were important milestones in British science education. The importance of these new approaches by the teachers themselves was appreciated by government but the pleas of the teachers for government support to extend the work were not supported financially. Instead the Nuffield Foundation, a British charitable educational foundation similar in many respects to the Ford Foundation, agreed to invest considerable money in supporting the teachers in project work which would amplify the policy statement and syllabuses prepared by the subject committees. Thus, the Nuffield Science Schemes were launched in 1961-62.

The original Nuffield science program was concerned with the production of new materials for the separate sciences—biology, chemistry and physics—at the GCE O level, i.e. a five year course in the three separate sciences for students aged 11-16 (Grades 7-11) ending with a new type of examination at the end of the fifth year. These original O level schemes were published in 1966 after initial trials in a representative group of schools. They are now being taught in an increasing number of British schools. Even so, after five years they have not been universally accepted or introduced but the philosophy behind the Nuffield schemes certainly has been incorporated in many new alternative syllabuses recently issued by the various examinations boards.

Having begun with the GCE O level stage for the more academically gifted children, the Nuffield Foundation was persuaded to invest additional funds into producing schemes of work in new science for the GCE A level—in separate physics, chemistry, biology and also combined physical science, as well as for the primary schools (Nuffield Junior Project). Also in 1967-68 a Nuffield scheme for *Secondary Science* for the average and below average students who may eventually take the Certificate of Secondary Education (CSE) was launched. This has now been published. At about the same time another scheme in integrated science was supported by the Nuffield Foundation, this time for the first two years of secondary education. It was intended to provide a general science course for students at the junior secondary level and is known as the Nuffield *Combined Science* Project. These projects have involved the Nuffield Foundation in a total investment of 2-3 million pounds. (about 5-8 million dollars).

Schools Council Support. In order to maintain the momentum of curriculum development in science the government, in 1964, launched a Schools Council for Curriculum and Examinations as a representative body of the Department of Education and Science, the LEAs, teachers, and other interested bodies in education.[4] The Schools Council receives financial support from the government and the LEAs to initiate educational research and curriculum development in all subjects in primary and secondary schools in England and Wales. Some of the original Nuffield Science schemes have been continued under School Council auspices. In addition, some new schemes have been launched. For example, the Schools Council Integrated Science Project is an attempt to produce a new scheme in integrated science right up to the GCE O level. Additional support has also been given to the Nuffield *Secondary Science* and to *Science 5/13*, an integrated science scheme for primary schools leading into the first two years of secondary schools or for the new middle schools which are developing in various parts of the country. In addition to supporting these schemes in school science, the Schools Council has also launched a major project in technology in schools; that is, an attempt to use project work to introduce applied science and engineering into the school curriculum.

In all these schemes, both the original Nuffield schemes and the more recent Schools Council projects, the members of the ASE who were involved in the early work on curriculum renewal and syllabus reform have been actively involved as team members. The original Nuffield science projects for the GCE O level, for instance, drew heavily on the subject committees of the SMA and AWST for the full time members. University staffs have been involved in an advisory capacity through consultative committees.

Scotland. In Scotland, very similar development work has been taking place from the early 1960's. Alternative syllabuses in chemistry, physics and biology were introduced into Scottish schools and teachers guides and laboratory work books were produced for trial purposes by the Scottish Education Department utilizing Scottish Inspectors and Scottish school teachers. These alternative syllabuses have now replaced the traditional syllabuses in the Scottish Certificate of Education. Also in Scotland within the last five years there has been a Scottish Integrated Science Project for the junior secondary level and also for the upper secondary level. In addition, Scottish schools are involved in trials of some of the Schools Council's projects such as *Science 5/13* (partly sponsored by the Scottish Education Department) and the Nuffield A level science projects.

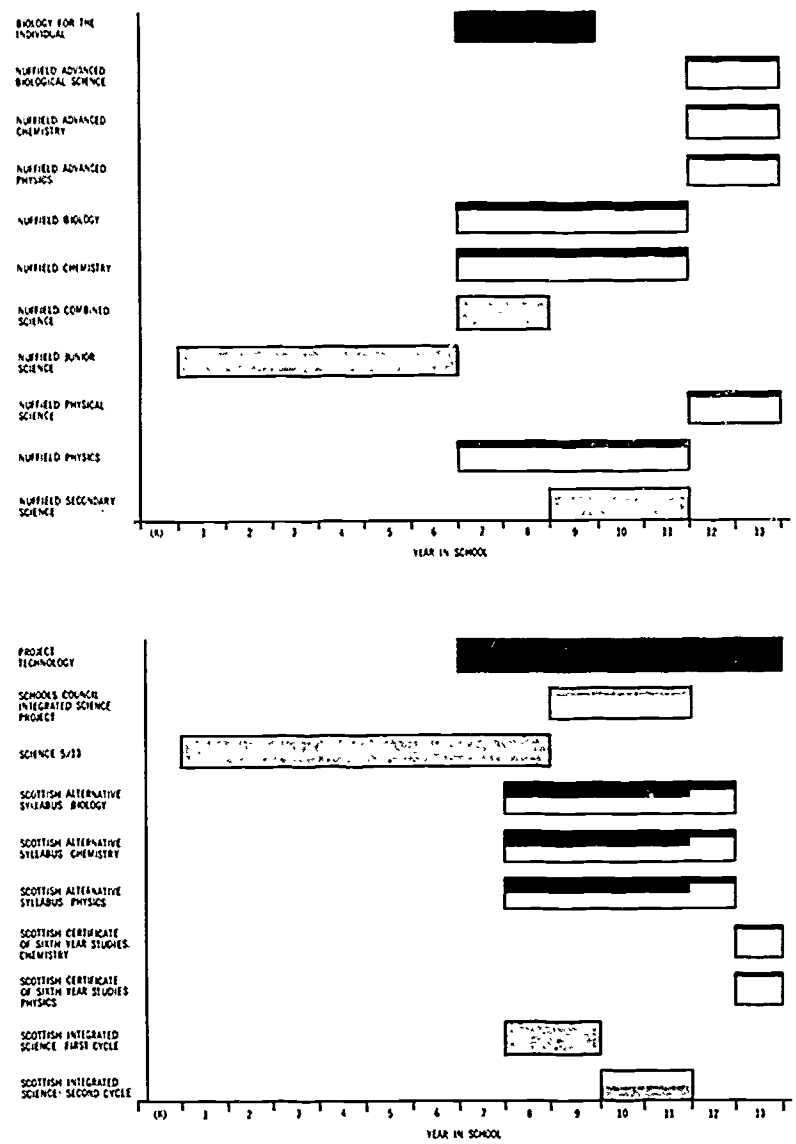
General Characteristics. The major characteristics of the new schemes now available to teachers are summarized in Figure 3.1. The second generation programs which integrate the major science disciplines at the secondary school level are described in detail in Chapters 4-7. The others are discussed briefly in Chapter 8.

These secondary school science curriculum projects have a number of features in common, particularly in the use of "stage managed heurism." They all emphasize active student involvement in laboratory or field experience; students are expected to design and execute some of their own experiments; and all projects aim to convey the spirit of science, deemphasizing a dogmatic assertion of fact. But, science by student investigation does not mean allowing a free-for-all romp with the apparatus and materials of science. The teacher must know where he wants the class to go, guiding them when necessary, and, while allowing students freedom to think, question, and experiment, being prepared to save students from frustration and waste of time by preventing them from going too far on unprofitable paths. "Part of the art of teaching is to give pupils as little indication as possible that they are being directed."

When asked to state their perception of the role of the teacher using these new programs, teachers usually gave an answer containing the same points as a Scottish College of Education lecturer who summed up the

FIGURE 3.1

Intended grade and ability range of British Science Curriculum Projects



The proportion of the rectangle shaded with different shadings for each project indicates the intended ability range. Light shading indicates projects that include some content from at least physics, chemistry, and biology. (For example, Nuffield Secondary Science is an integrated program intended for students in the lower 75% of the ability range; Nuffield Physics is written for the most able 25% of the age range.)

expected role as

An introducer of topics;
an advisor to groups or individuals; and
a synthesizer and consolidator at the end of sections.

In many of these projects no "textbook" was produced by the development team. (Nuffield O-level Biology is an exception; textbooks have been written for the Scottish syllabuses, but they were not produced as part of the preparation of the courses.) In this way teachers have been able to retain their flexibility of approach. In most of the programs the only published materials are teachers guides and resource books. Others also provide background readers and guides to experiments for pupil use. However, some commercially sponsored publications "along Nuffield lines," have appeared for use by students.

Implementation. Many teachers of the new programs feared that they would not have the confidence to handle classes with open-ended approaches to investigational problems, having themselves qualified by the more rigorous methods of didactic teaching. Similarly teachers of the newer non-specialist "integrated" programs felt that they would not be competent to teach the necessary range of concepts from each of the traditional disciplines. These feelings are, in part, a reflection of the background of the teachers, who, by United States standards, have had a very specialized training. Typically they would have completed a degree program consisting almost entirely of courses in *one* of the major disciplines. Implementation of programs such as Scottish Integrated Science, *Combined Science*, or *Secondary Science*, which are all to some extent "integrated" or "unified" curricula, has therefore depended on providing teachers with sufficient content background skills and confidence to teach subject matter outside "their" specialty.

The methods used to provide this confidence include an initial use of forms of "team teaching" within the school, with each teacher responsible for specific portions of the work. This is, however, contrary to the spirit of the programs, which have been designed with the intention of one-teacher, one-class. Teachers have been provided with opportunities to become acquainted with the philosophy and content of the courses through inservice courses arranged by the curriculum developers themselves, Colleges of Education, LEAs, or Teachers' Centers. The intensive inservice courses range from ten-week courses in, for instance, Nuffield Physics at the Worcester College of Education, to two-week residential programs at Birmingham College of Education where teachers preparing to teach Nuffield *Combined Science* obtain practical experience with all portions of the suggested program. Teachers trained by the curriculum development team assist with dissemination within their own Education Authority. For example, one hundred teachers nominated by LEAs have been trained as *Secondary Science* teacher-leaders at the Chelsea Centre for Science Education. Continual assistance is also offered at local Teachers' Centers.

The Teachers' Centers[5] serve as a venue for short meetings with project organizers; as centers for demonstration and display of apparatus; and as a point of contact for teachers who can share and solve common problems Some, such as the Edinburgh center, contain small science laboratories used by science advisors to demonstrate techniques at short inservice workshops. Where they exist, the centers have facilitated the introduction of the new courses.

One of the strongest forms of "inservice training" that has occurred takes place within the school. In Scotland, particularly, many schools arrange their timetable so that all the science staff have a preparation period at the same time at least once a week. This time is scheduled as a departmental meeting where department policy is discussed and potential difficulties are ironed out. A "specialist" teacher may demonstrate techniques to be used in the coming weeks, and clarify any conceptual difficulties his colleagues may have. One of the Scottish HMIs reports that this system operates in about three-fourths of Scottish schools, and that these schools have had least difficulty in introducing Integrated Science. In some of these schools, where there is a strong team spirit within the science department, it is not unusual for teachers to move in and out of each other's classrooms, so that they can obtain more direct experience of teaching techniques appropriate to science concepts not within the scope of their training. Such open departments are not the rule, however.

One important point that needs to be clearly understood is that despite the existence of the public examination systems, the new curricula were by no means imposed by the examinations boards. In England, it was necessary to arrange for one of the Boards to offer the appropriate examinations before trial teaching could occur. In a very real sense, the Boards acted as servants of the teachers developing the courses, not their masters. This is particularly true of the CSE boards which can allow teachers complete freedom to develop their own program, including their own examinations, via one of the alternate CSE modes. The Boards act as a body recognizing the standards of these courses which require Board approval. This mode is likely to prove more important as teachers prepare their own courses from resources provided by programs such as Nuffield *Secondary Science*.

Even in Scotland, with its single examination board, and a closer relationship between the Education Department, examination board, inspectorate, and syllabus prescription, teachers were initially able to choose between the old and the "alternative" version of the science examinations. With the increasing popularity of the "alternative" syllabuses, the old examinations were phased out, and only one examination is now offered. This is not true in England, and a large variety of examination courses are offered, including those still based on "traditional" syllabuses.

In contrast to the Scottish situation, it is extremely difficult to estimate the number of children in England and Wales taking courses based on the new curricula. Even the crude measure of "textbook sales" is inappropriate, for most of the projects do not provide student textbooks, but are basically teachers resource materials. Since the guides contain some ideas useful in even the most traditional course, an estimate based on sales would be likely to overestimate the number of teachers teaching a "Nuffield program." Similarly the short readers and loop films provided by many of the projects can be used as aids in most courses. However, we believe that about half the schools are using at least one of the modern curriculum projects.

4

SCOTTISH INTEGRATED SCIENCE COURSES

The course commonly referred to as "Scottish Integrated Science" differs from most modern curriculum projects in the manner in which materials were produced. The major purpose of establishing the 1964 working party was to review existing science curricula for Scottish students in non-certificate courses, and to consider the application of the principles of the recently published "Alternative Syllabuses" (see Chapter 8) to these lower-level courses. The working party was *not* established to produce materials for use by students and/or teachers.

In 1966, with the advent of a plan for universal comprehensive education, implying that the early years of secondary schools would contain academically homogeneous classes, the terms of reference of the working party were changed. Its function then became to:

> Carry out a comprehensive review of the present curriculum in science in
>
> 1. the first two years of secondary education;
> 2. the later years of secondary education for non-academic pupils . . . and to report.[1]

In conducting the review the working party did not merely pinpoint faults in existing courses, but took the broader approach of preparing a workable syllabus, and evaluating it in schools. The syllabus for the first two years (Grades 8-9) that resulted from this approach is now known as *Scottish Integrated Science.*

It was, of course, necessary to distribute some materials during the testing of the syllabus in the selected schools: worksheets provided during the trials and revised after feedback from the schools are now available commercially. The function of worksheets is discussed later in this chapter. At a later stage textbooks following the order of the syllabus outlined in *Curriculum Paper 7* were written. These books, and their associated teachers' guides, are also described in this chapter.

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SCIENCE FOR THE FIRST TWO YEARS

The Syllabus

Since the first two years of secondary education is the only time that it is certain that all pupils in all Scottish schools study science, those aspects of science that best contribute to general education are emphasized. An attempt has been made to provide an introduction to scientific language, and to expose students to the experimental methods of scientists, the apparatus used, and the methods of drawing conclusions.

With these "general education" aims in mind the working party has formulated both general objectives (expected to be attained after frequent experiences of a particular type) and specific objectives, for which particular parts of the syllabus are designed. The successful attainment of many specific objectives will be necessary to achieve successfully any one general objective. The stated general objectives are:

[Pupils should acquire] . . .

(A) **in knowledge and understanding**

1. knowledge of (i.e. ability to recall) some facts and concepts concerning the environment
2. knowledge of the use of appropriate instruments in scientific experiments
3. an adequate scientific vocabulary
4. an ability to communicate using this vocabulary
5. comprehension of some basic concepts in science so that they can be used in familiar situations
6. ability to select relevant knowledge and apply it in new situations
7. ability to analyse data and draw conclusions
8. ability to think and act creatively in science

(B) **in attitudes**

9. awareness of the inter-relationship of the different disciplines of science
10. awareness of the relationship of science to other aspects of the curriculum
11. awareness of the contribution of science to the economic and social life of the community
12. interest and enjoyment in science
13. an objectivity in observation and in assessing observations

(C) **in practical skills**

14. some simple science-based skills
15. some experimental techniques involving several skills.[2]

The specific objectives for section 10, *Hydrogen, Acids and Alkalis,* serve as an example of the type of statement provided to guide teachers:

[Pupils should acquire] . . .

in Section 10

1. knowledge of a test for the identification of hydrogen

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2. the knowledge that water is formed when hydrogen is burned
3. the knowledge that certain metals react with water at room temperature (sodium, calcium, magnesium)
4. the knowledge that certain metals displace hydrogen from dilute acid (magnesium, aluminum, iron, tin)
5. the knowledge that other metals do not displace hydrogen from dilute acid (lead, copper, silver, mercury)
6. the knowledge that there is a graduation of reactivity among the common metals
7. the knowledge that pH is a measure of the degree of acidity of a solution
8. the knowledge that acid and alkali are names given to solutions at opposite ends of the pH scale
9. the knowledge that acids neutralize alkalis
10. the knowledge that there is a simple quantitative relationship in neutralizing acids with alkalis
11. awareness of the processes involved in identifying a chemical substance
12. awareness of the use of standard scales for comparison purposes
13. skills in handling simple chemicals and glassware
14. awareness of dangers of handling hydrogen in large quantities.[3]

There are similar lists for each of the other fourteen sections of the syllabus.

One constraint on the selection of content for the Scottish Integrated Science syllabus resulted from the expectation that many students will follow these initial studies with courses in one or more of the constituent sciences to O grade or beyond. For this reason close consultation with the relevant panels of the Scottish Certificate of Education Examination Board produced physics and chemistry components of the integrated course identical with the content of the concurrently revised separate "alternative syllabuses." The wording is not identical in the biology sections of the two syllabuses, but the Integrated Science material is drawn from the biology syllabus of the examination board. From this material a single course has been written, providing basic content for further work in science, and, at the same time, providing a terminal course for those students who will study no more science. Table 4.1, p. 23, summarizes the resulting course.

When examining Table 4.1 it is important to remember that a basic tenet of the working party is that during the first two years of secondary education science courses should be primarily observational in nature. This emphasis influences the selection o, ontent, and the extent that explanation of phenomena is emphasized.

Explanation is not omitted, however. Some explanatory models are introduced early, and students do use them in other sections of the course. For example, a class beginning section 5.2 of the syllabus (see Table 4.1)

TABLE 4.1

Scottish Integrated Science Syllabus: Summary Table

(Reproduced from Scottish Education Department. Consultative Committee on the Curriculum. *Curriculum Papers 7: Science for General Education: For the First Two Years and the Early School Leaver* (Edinburgh: Her Majesty's Stationery Office, 1969). pp. 20-21)

Section 1. Introducing Science
- 1·1 Laboratory techniques
- 1·2 Experiments with observations and some conclusions

Section 2. Looking at Living Things
- 2·1 An investigation of a living organism
- 2·2 Diversity of form
- 2·3 The idea of classification

Section 3. Energy—The Basic Idea
- 3·1 Forms of energy
- 3·2 Energy interconversions
- 3·3 Energy converters in action
- 3·4 Energy and living things

Section 4. Matter as Particles
- 4·1 Evidence for the fine division of matter
- 4·2 Structure of matter
- 4·3 Kinetic theory
- 4·4 Applications

Section 5. Solvents and Solutions
- 5·1 Water cycle
- 5·2 Solubility and its uses
- 5·3 Emulsions and colloids
- 5·4 The process of digestion

Section 6. Cells and Reproduction
- 6·1 Cells and living things
- 6·2 Role of cells in reproduction
- 6·3 Methods of achieving fertilisation
- 6·4 The growing embryo

Section 7. Electricity
- 7·1 Electricity at rest
- 7·2 What is electricity?
- 7·3 Electricity in motion
- 7·4 Opposing the current
- 7·5 Heating by current
- 7·6 Driving the current
- 7·7 Introduction to electricity at home

Section 8. Some Common Gases
- 8·1 Oxygen, nitrogen and carbon dioxide
- 8·2 Energy intake and photosynthesis
- 8·3 Unbreathed and breathed air
- 8·4 Composition of air
- 8·5 Solubility of air in water
- 8·6 Release of energy—respiration
- 8·7 Respiratory system

Section 9. Making Heat Flow
- 9·1 Methods of heat transfer
- 9·2 Problem situations

Section 10. Hydrogen Acids and Alkalis
- 10·1 Hydrogen
- 10·2 Burning of hydrogen
- 10·3 Action of metals on cold water
- 10·4 Action of metals on dilute acid
- 1[illegible] Acids and alkalis

Sec[illegible] Detecting the Environment
- [illegible] The eye and light
- [illegible] Vision
- [illegible] The ear and sound
- [illegible]4 Balance
- 11·5 Taste, smell and other senses

Section 12. The Earth
- 12·1 Origin and structure of the Earth
- 12·2 Naturally occurring elements
- 12·3 Naturally occurring sulphides, oxides and carbonates
- 12·4 Silica and Silicates
- 12·5 Coal
- 12·6 Oil
- 12·7 Salts from the sea
- 12·8 The soil environment

Section 13. Support and Movement
- 13·1 The idea of force
- 13·2 Work and energy
- 13·3 Support in plants
- 13·4 Support in animals
- 13·5 Muscles

Section 14. Transport Systems
- 14·1 Types of food; balanced diet
- 14·2 Teeth
- 14·3 Other methods of feeding
- 14·4 The digestive system
- 14·5 Need for a transport system
- 14·6 Types of transport system
- 14·7 Getting rid of body waste and poisons
- 14·8 Excretion in plants and animals

Section 15. Electricity and Magnetism
- 15·1 Dangerous and safe materials
- 15·2 Electricity in the home
- 15·3 Electronics
- 15·4 Electric lighting
- 15·5 Electromagnetism
- 15·6 Electricity supply

was adding successive 1 g samples of substances to 20 cm^3 of water. The following conversation took place between one group and one of the authors of this report:

"How much of that substance have you added to the water?"

"Three spatulas full."

"Where has all the salt gone?"

"Its dissolved, I suppose."

"What do you mean, dissolved?"

"Well, the salt particles have moved about. Gone between the water ones."

"Have you had results like this in other experiments?"

"Yes, it's just like how the particles of that red gas moved between the particles of the air."

In section 12, students are expected to produce "explanations" by using observed patterns. The metals magnesium, aluminum, iron, zinc, tin, copper and silver are heated in a stream of oxygen, and then with sulfur. The activity series resulting from these two sets of experiments is used to explain why only certain metals are found naturally in the elemental state, and to predict which metals will be most easily obtained from their ores by smelting with "an element which has a stronger 'pull' on oxygen than the metal has."(4)

Almost all explanations used in this syllabus are similar to these two examples, being either the qualitative application of a model or the use of experimentally observed patterns. Few exact quantitative explanations or generalizations are expected. Even in the electrical sections the relationship between potential difference and current flow is only intended to be taken as far as "when the voltage increases, so does the current." Deliberate steps have been taken to minimize exact quantitative determinations. *Relative weight* is used instead of *density,* for example, "because the latter seems to invoke in the minds of some science teachers the performance of an interminable series of experiments and subsequent problems on density determination."(5)

It will be noted from Table 4.1 that many sections of the syllabus contain work that is identifiable as physics, chemistry, or biology. The working party did not attempt to "integrate material in any artificial way."(6) Only where the subject matter falls naturally together is any integration attempted, and the working party considers that only in sections 1 and 3 are all three component sciences linked. However, in seven of the remaining sections content from two of the major sciences is included. Section 12, which the working party considers to contain material from chemistry and biology, also contains material that could be considered as "earth science," although little structural geology is included.

Relationships of science and society are included wherever there is a natural connection:

> It is one of the general aims of this course to expose the pupils to some of the fundamental cultural aspects of science, and this section [12] provides a good vehicle for this purpose in the first two years. The significance of metals in the history of man is clearly related to the ease with which they can be isolated; the present search for other metals as new and more exacting specifications are demanded; and the economic importance of such developments to the nation can all be incorporated in the class discussions which will arise during this work. Such discussions are equally possible in connection with silica and silicates as refractories and building materials, and in dealing with coal, gas and oil as the traditional sources of energy. The emerging importance of the sea as a reservoir of metals and of energy should not be ignored.(7)

Similarly, everyday applications are stressed, particularly in the two electrical sections.

The organization of the material in the final syllabus is a result of feedback during the trial years. This feedback took the form of written reports of teachers; observations during visits to the classrooms (by Her Majesty's Inspectors, members of the working party and local science advisers); reports of discussion groups held at local and national levels; and quantitative data from pre- and post-testing of specific sections in various schools. The final order is not rigidly prescribed, but is an order that has been found to work. For example, in the original drafts of the course the present two sections concerning electricity were presented as one unit early in the first year. This was found to be unsuitable as students found the work rather complex.

There are some sections, however, that are most effectively taught in the suggested sequence. Sections 1 and 9 are both intended as interesting introductions and it is recommended that they be used to begin years 1 and 2 respectively. Since energy and the particulate nature of matter are fundamental to many later sections, teachers are advised to schedule them early in the course. However, the order in which they are taught is immaterial.

This flexibility is used in many schools to obviate the need for large stocks of apparatus. For example, in one Edinburgh school all the first year classes study section 1, then section 2, (sections requiring minimal complex apparatus); half the classes then follow section 3 while the other half studies section 4; they then change over. After both classes complete all four sections the entire first year studies sections 5 and 6. Sections 7 and 8 are then treated alternately.

Section 6, cells and reproduction, has been placed in a sequence that means that it is being taught in the middle of the first year (grade 8). Much information from trial schools substantiates this placement. For most students this appears to be the appropriate age (approximately 12-13 years) for a discussion of the basic facts of reproduction, including human reproduction. Schools that delay this section until the second year find that student attitudes make teaching fairly difficult.

Recommended Teaching Techniques

In common with other new science curricula of the past decade, the Scottish Integrated Science course involves extensive laboratory work, most of it conducted by the pupils. Two-thirds of the approximately 260 suggested sets of experiments contained in *Curriculum Paper 7* are intended to be conducted by pupils, individually or in small groups. The remaining teacher-demonstrations consist mainly of experiments that are not suitable for students. Some require elaborate apparatus, e.g., the evacuation of a discharge tube connected to an EHT power pack; others require skilled technical manipulation or special techniques, e.g., latex injection of a fresh lamb kidney. In some cases demonstrations are recommended during the introduction of a new topic, especially where spectacular effects are possible, e.g., "the pupils expect a dramatic introduction with sparks and hair raising experiments"(8) at the beginning of the electrical section. However, the most important reason for using demonstrations is one of safety. Where an exercise is thought to be very useful in establishing a particular point, but is too dangerous for students to undertake, a demonstration is highly recommended. The reaction of sodium and water, the direct combination of chlorine and copper foil, and the use of 240V household current in some experiments in the electrical sections are representative examples.

The majority of the pupil experiments require simple, cheap and relatively robust equipment, and it is expected that all pupils will conduct these exercises singly or in some groups. If the apparatus is only available to schools singly or in small numbers a "stations" technique is suggested. Here there will be "various experiments each representing some aspect of the same concept, set out around the laboratory so that pupils in small groups can circulate from one to the other. Care must be taken here to ensure that these can be done in almost any order, otherwise circulation will be restricted and time wasted in waiting for particular experiments."(9) This is the same technique that is referred to as a "circus" in England. Examples of the content of a circus of experiments are given in Chapter

5, Nuffield Combined Science.

Scottish schools treat science as a "practical subject," and limit class size to 20 (often involving splitting a normal class unit). Although the syllabus has been planned accordingly, it is reported that schools in Malaysia and other countries are experiencing little difficulty using the course in larger classes. Similarly, even though all the teachers visited had laboratory technicians, and deemed them vital for the success of the course, only about half of the Scottish schools presently have technicians. Nevertheless schools without this assistance have successfully introduced Integrated Science.

Table 4.2, p. 28, a portion of the syllabus for section 11, illustrates the careful psychological, rather than logical, sequencing of activities built up as a result of experience in the trial schools. The use of pupil manipulation and experimentation to provide a sufficient basis for concept development and the expectation that the teacher will consolidate and reinforce the principles, often by demonstrations, is also evident.

Although a detailed list of suggested experiments to be conducted by the pupils, and demonstrations to be staged by the teachers, is given, the syllabus does not provide details of experimental procedure. Pupils can obtain most of the information needed from the worksheets written by the working party. These instructions are often a combination of a simple diagram and a small amount of text, (See Fig. 4.1, p. 29). Teachers are provided assistance with experimental procedure, for demonstrations and for activities, by a number of sources. The working party has provided a set of *Memoranda for Teachers*, written by teachers who taught the course in pilot schools. These contain more detailed guidance on the teaching of each section than is provided in the syllabus. Comments on experimental detail, or reference to sources likely to be in the school, are provided for almost all laboratory work specified in the syllabus. In addition, the *Memoranda* contain comments on the level of understanding expected, outlines of possible homework exercises, suggestions for extended work on the topic, some general references and, if applicable, notes on films related to the section.

Ideas for simple experiments to clearly develop a concept, or for demonstration apparatus, are regularly provided in the bulletins of the Scottish Schools Science Equipment Research Centre (SSSERC). This center is supported by all 35 Scottish local education authorities. It tests and reports on the suitability of commercial products, as well as designing new apparatus suggested by teachers or modifying and constructing equipment reported in the educational press. Instructions are provided by SSSERC to help the science technician construct much of the newly

TABLE 4.2

Portion of the detailed syllabus for Scottish Integrated Science

The symbols P,S, and D against the suggested practical work denote the type of work recommended: P indicates a small group or individual pupil experiment; S indicates that the committee recommends a "stations" technique (see text); and D denotes a teacher demonstration.

(Reproduced from Scottish Education Department, Consultative Committee on the Curriculum, *Papers 7; Science for General Education: For the First Two Years and the Early School Leaver* (Edinburgh: Her Majesty's Stationery Office, 1969), pp. 83-84)

Section 11. Detecting the Environment

The sensory nerves and their limitations are considered. Subjective anomalies are pointed out. The physics of light and sound is treated observationally. No attempt is made to interpret them in terms of photons or waves.

Suggested time allocation:—24 periods.

Subject Matter	*Explanatory Notes*	*Suggested Practical Work*
11.1 The eye and light.	Structure of the eye in relation to sight.	P. Dissection of eye.
	Note—lens, iris, choroid coat and nerve. Relate curvature of lens to muscles of eye.	P. Squeeze lens to show that shape can be altered.
	Starting with the pinhole camera, study the role of the converging lens in focusing light on a photographic film or the retina.	P. Pinhole camera made.
	Rays can be traced through prisms and then lenses of different curvature.	P. Rayboxes, prisms and lenses. Ray tracing through prisms base to base, then through converging lenses. Relate position of focus to curvature, qualitatively.
	This work can then be applied to both the camera and eye.	D. Camera with lens.
	Resemblance of eye to camera—lens, blackened interior, light sensitive surface.	D. Model of eye using flask.
11.2 Vision.	Colour is seen only in centre of retina. Other limitations of eye. This is intended as a survey of the areas where accepted signals break down and the brain interprets the signal from the eye incorrectly. A series of little experiments can be laid out and covered in one double period.	P. Colour vision test cards. P. Find blind spot on eye. S. Single eye vision: optical illusions in shape and colour.

FIGURE 4.1

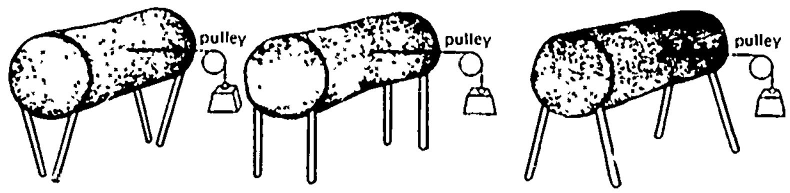
A worksheet prepared for the Scottish Integrated Science syllabus

(Photographically reduced from *Science Worksheets Prepared by the Scottish Secondary Science Working Party. Year Two—Sections 9 to 15* (London: Heinemann Educational Books, 1969), Worksheet 13/7)

Science Worksheets **Section 13**

Sheet 7

Stability in animals



1 Roll 50 g of plasticine into a cylinder 4 cm long. Attach 4 half length (8 cm) straws as legs, in the way shown in the diagram. Add weights to the balance until the model topples. Find the number of grams needed to topple each model.

No. of grammes

1 ______ This is a force of ______ N
2 ______ This is a force of ______ N
3 ______ This is a force of ______ N

2 Which is the most stable model?

What force was required to topple this model?

3 Using the same cylinder, attach legs of full length (16 cm) and quarter length (4 cm) straws in the most stable model found in 1. Complete the table opposite.

Length of straw	Number of grammes required to topple model	Force required to topple model (N)
Full		
Half		
Quarter		

4 Which length of leg gives the greatest stability?

5 Which is the most stable structure in terms both of arrangement and length of leg?

6 Draw from the side the most stable arrangement of legs for this cylinder.

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developed equipment in the school science workshops. "These instructions are detailed to the point where we think the rawest recruit, or even the teacher himself, will be capable of assembling the equipment."[10]

Materials Available

Worksheets. Worksheets written by the working party completely cover the first year's work (sections 1-9), but many parts of the second year are not treated. Teachers are urged not to prepare their own worksheets for the omitted sections, but to " take such opportunities to discover how far along the road to self-reliance pupils may have gone. This should be seen as a beginning to the slow process of removing the props."[11]

In addition to providing instruction or experimental procedure for the pupil, the worksheets are designed to lead students through a reasoning sequence without providing the final "correct" answer (See Fig. 4.1). While the working party feels that science classes should ideally be arranged to allow the pupil to select the approach and method, they recognize that the students have "neither the skills nor experience to work on their own without support."[12] Worksheets are, therefore, structured and their use is described as "stage-managed heurism."[13] Some elements of "discovery" remain, but the situation is provided, and in most cases, techniques suggested. Care is taken that the "discoveries" made are consistent with a particular scientific principle or concept.

As far as possible, each worksheet is hierarchical in arrangement, with the later frames requiring increasing depth of thinking, usually at the application or higher levels of Bloom's taxonomy.[14] An attempt has been made to make it possible for slower students to grasp the "essential point" of the exercise without completing all the work on the sheet. Additional exercises, often providing more divergent situations, are included for the more able students. One of the HMI members of the working party estimates that average students will probably finish most worksheets, with a small number of very able students requiring more work than is provided on the sheets. The grading of frames within the sheets is an attempt to provide for individual differences within the group teaching situation.

Many schools produce their own worksheets, often revisions of the commercial versions modified in light of experience within the particular school. Some are written to fill in a gap, or extend the depth of treatment of the original series. Teachers who prepare their own worksheets are encouraged to use a similar arrangement to that used by the working party, particularly with respect to the gradation from lower to higher cognitive skills.

Teachers and other educators repeatedly emphasize that the worksheets are not the entire course and are not to be seen as something to be given to students who are then left on their own. "The introduction to the work on the worksheets, the discussion afterward. . all of the demonstration work and the actual teaching which will establish the concepts are still completely in the teacher's hands."[15] Anyone examining the worksheets must keep this firmly in mind, if he is not to be seriously mislead.

Textbooks and Teachers' Guides. The two pupils' texts and associated *Teachers' Guides* published under the general title *Science for the 70's* were prepared to follow the order of the syllabus published in *Curriculum Paper 7*. The books are not products of the Working Party *per se*, although two of the three authors were also members of that group. In this respect the books are not products of a "curriculum project."

The *Teachers' Guides*, although published as part of the *Science for the 70's* package, also contain comments on experiments designed to help students meet the objectives listed in *Curriculum Paper 7*. These comments help clarify the somewhat cryptic syllabus statements. However, details of experimental apparatus illustrated in the pupils' texts or in the worksheets are not repeated in the *Teachers' Guides*.

The guides describe sets of laboratory activities suitable for evaluation and testing, as well as a number of tested multiple-choice items for each section of the syllabus. An examination of these items indicates the importance placed on higher level cognitive skills in Scottish Integrated Science. For each section there are items at each of the comprehension, application, and synthesis/evaluation levels as well as those testing recall of information.

The pupils' books in this series are best characterized as a combined laboratory manual/textbook. Suggested experiments, with procedural details and apparatus diagrams are intermingled with explanatory illustrations or extension materials. An attempt has been made to preserve the "inquiry" flavor of the "stage-managed heurism" advocated by the writers of *Curriculum Paper 7* by posing a series of leading questions in the text. However, the competing demands of an expository text make this difficult. The nature of the compromise reached can be seen in Figure 2, p. 32. Pupils are not given *all* the answers to the questions posed in the text, but many can be answered by reading a few more paragraphs, where a particular answer has been assumed in the further development of the text.

SCIENCE FOR SECOND-CYCLE, NON-EXAMINATION STREAMS

Curriculum Paper 7 gives considerable attention to the nature of

FIGURE 4.2

Sample page from Science For The 70's

(Photographically reduced from A. J. Mee, Patricia Boyd and David Ritchie. *Science for the 70's. Book 2* (London: Heinemann Educational Books. 1971). p. 17)

Make a list of those metals you know which *can* turn out hydrogen from water and those which cannot.

One of the metals which cannot turn out hydrogen you have found to be copper. What would you expect to happen, then, if you passed hydrogen over heated copper(II) oxide? Devise an apparatus for seeing if you are right.

You are expecting the hydrogen to take the oxygen away from the copper(II) oxide and form water. If you are to prove this, what must you be sure about regarding the hydrogen and the copper(II) oxide?

To make sure that the copper(II) oxide is dry, your teacher will have heated some in a dish and allowed it to cool in a dry atmosphere. This is done in a vessel called a desiccator. To dry hydrogen it is passed through a drying agent called silica gel. You have met this before in Unit 5.

Sum up in one line what has happened when hydrogen was passed over heated copper(II) oxide. What would you expect to happen if you passed hydrogen over heated magnesium oxide, and over heated lead oxide?

10.10 Acids

Acids have often been mentioned in this book. Make a list of any you can remember. Have you included sulphuric, hydrochloric, and nitric acids? These are the commonest acids we use in the laboratory and we have met all of them – one as recently as the last paragraph.

The word 'acid' means 'sour'. We often say that a sour liquid tastes 'acid'. Are there any sour liquids you come across at home? What about vinegar, lemon juice, grape-fruit juice, tartaric acid, citric acid, and sour milk? All these are acids, or mixtures of acids. Vinegar contains acetic acid, lemon juice and grape-fruit juice contain citric acid (you have heard of citrus fruits), and sour milk contains lactic acid.

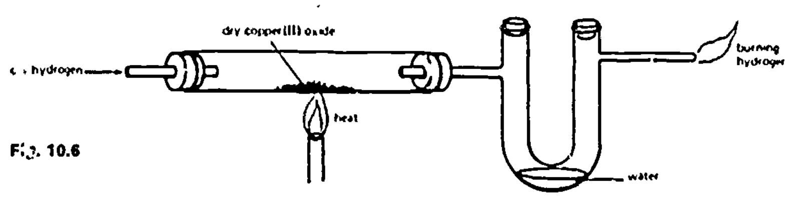


Fig. 10.6

The apparatus is shown in Fig 10 6 Is it anything like the one you thought of? When the hydrogen has swept all the air out of the apparatus the copper(II) oxide can be heated, but not before. Why is this? What happens in the U-tube? You think water may have collected. What tests would you carry out on the liquid to find out?

What has happened to the copper(II) oxide? Some time ago (Unit 4) you saw what happened when nitric acid was added to copper, but if you have forgotten, try it again. In one test-tube put some copper turnings, in another some copper(II) oxide, and add some dilute nitric acid to each. Can you use the results of this experiment to distinguish between copper and copper(II) oxide? When the apparatus is cool, take out the brown powder and try the nitric acid test on it.

Fig. 10.7 A nitric acid plant

science instruction for students in years 3 and 4 (Grades 10-11) who do not intend to follow courses leading to Scottish Certificate of Education courses. The working party considered this problem in the light of previous Scottish reports[16] which recommended that each discipline should identify "aspects of the particular discipline which can be integrated with similar material from other disciplines to form broadly based courses dealing with various aspects of moral and social education, preparation for leisure and vocation based activities, and presented by a team of teachers from among the various specialist groups."[17]

As well as providing the information that contributes to the broadly based "integrated" courses, the second cycle is seen as the time when the fundamental concepts established in the first two years are applied to realistic everyday situations, when problem solving techniques are consolidated, and when appropriate understandings, skills, and attitudes will be manifest.

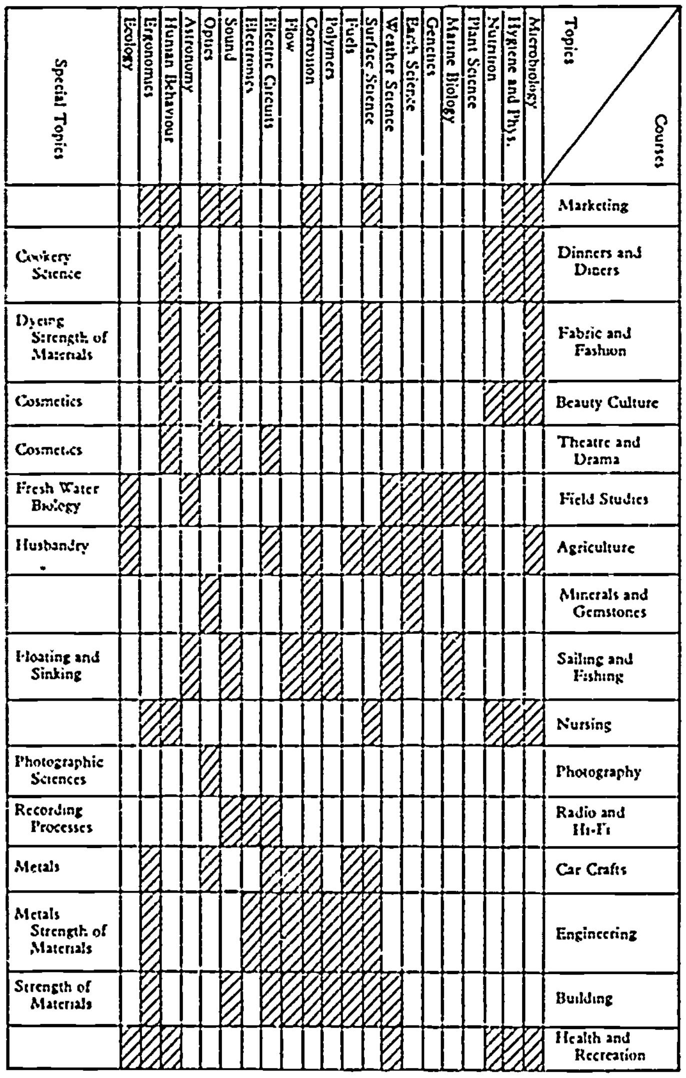
There are no firm recommendations for local, multi-disciplinary courses for all schools, since the setting of the school will determine the most appropriate curriculum for its students. However, in order to illustrate ways in which science can contribute to such local courses, a chart was prepared relating the most common courses taught in the third year to appropriate science topics (Fig. 4.3, p. 34). The vertical axis of the grid is composed of the science topics that contribute to a number of courses. Topics that are specific to, and considered essential for the development of, a particular course are indicated in the bottom row of the column for each course.

Outlines for a number of the topics have been prepared and tested in a variety of schools. The topics are intended to take from six to eight weeks to complete. Each topic has been planned to accomplish the dual purpose of providing information relevant to the course and creating experimental situations to provide practice in using the scientific intellectual skills and problem-solving methods established in the first two years. Outlines for eighteen of the thirty suggested topics are available. Each outline follows a similar form to the syllabus for the first two years, with a synoptic statement of the subject matter, explanatory notes, and suggested individual, group, or demonstration experiments. Where appropriate, lists of teacher and student reference material and notes on unusual experiments are appended. The topics for which outlines are available[18] comprise the bulk of those indicated in Fig. 4.3, and are expected to be sufficient to allow any school to provide a full year of science study in any of the listed courses. The topics are microbiology, marine biology, fresh water biology, plant science, nutrition, human sciences, earth science, fuels, dyes, corrosion, surface science, photographic science, optics,

FIGURE 4.3

Suggested science topics for selected courses designed for second-cycle non-certificate courses in Scotland

The horizontal axis of the grid lists the most common courses taught in schools offering non-certificate programs for students in the third and fourth years of Scottish secondary schools (grades 10 and 11); the vertical axis lists science topics that may contribute to a number of these courses. The shaded areas indicate the courses for which these topics are considered appropriate. Topics that are specific to, and considered essential for the development of, a particular course are identified in the bottom row of the column for each course. (Photographically reduced from Scottish Education Department, Consultative Committee on the Curriculum, *Curriculum Papers 7: Science for General Education: For the First Two Years and the Early School Leaver* (Edinburgh: Her Majesty's Stationery Office, 1969), p. 36.



astronomy, weather science, flow, electric circuits, and electronics. The outlines of three of these topics, electrical circuits, weather science, and human sciences, are also available in Appendix 3 of *Curriculum Paper 7*.

Although there are numerous suggested topics, no more than five or six topics are expected to be included in the science work for each year. It is recommended that the courses and topics be chosen to allow non-examination students to attain the science objectives stated for this cycle of work. The objectives emphasize attitude development in addition to appropriate knowledge and skills for social, leisure, and vocational interests. The objectives are that:

Pupils should acquire,

(A) **in knowledge and understanding**

1. some facts about scientific aspects of various industries and occupations in the community
2. some facts about the scientific aspects of various leisure pursuits
3. some facts and principles in scientific aspects of various topics of social importance to the individual and to the community
4. information about some aspects of science such as sociology and psychology and about some of the methods by which this information is obtained
5. a knowledge of the function and use of other and more complex scientific instruments and equipment
6. ability to communicate information and ideas about science
7. greater comprehension of some basic concepts in science so that they can be used in familiar situations
8. greater [illegible]ility to select relevant knowledge and apply it in new [illegible]ns
9. greater ability to analyse data and draw conclusions
10. greater ability to think and act creatively in science

(B) **in attitudes**

11. aware of the relationship of science to other disciplines of knowledge
12. awareness of the importance of science in the working, leisure and social aspects of the community and society in general
13. an interest and a willingness to participate in science-related leisure pursuits
14. willingness to conform to and an interest in propagating sensible rules for safety and good health for the sake of the community, as well as of the individual
15. an interest in and a willingness to participate in conservation of the natural environment
16. an interest in gathering information about science through all the media of communication
17. an appreciation of man's responsibility to use science for the benefit of society
18. an attitude of objectivity to all decisions and assessments required of the individual

(C) **in practical skills**

19. further laboratory skills
20. some laboratory techniques relevant to later vocational, domestic or leisure needs.[19]

5

NUFFIELD COMBINED SCIENCE

The earliest Nuffield Foundation courses provided materials, described in Chapter 8, for separate courses in physics, chemistry and biology from the first year of secondary school. The introductory portions of these courses were designed as part of a sequence leading to an O level examination and, accordingly, were primarily intended for the academic top 25 percent of the student population. The *Combined Science* team, set up in 1966, had the task of synthesizing these materials to provide work suitable for children in the first two years of British secondary schools. Simultaneously, they were faced with the task of adapting the materials to provide for the full range of student abilities as secondary schools became "comprehensive" and mixed-ability teaching became common in the early secondary years.

In many ways this was a similar situation to that which the Scottish working party on secondary science encountered, with the important exception that the Scottish team had to produce a course that would also be suitable for students of higher ability than the original group specified in their brief. Both groups were obligated to prepare students for a number of possible eventualities: students from their courses might proceed to study one or more separate specialist sciences to external examination level; they might take unexamined science courses; or they might not study any more science.

There was a strong obligation for the *Combined Science* team to utilize the existing equipment designed for the first two years of the separate Nuffield O level courses. Much of it was specialized and expensive, and the need for additional special apparatus was to be minimized.

The equipment constraint was not absolute, and the team was not merely editors synthesizing in a logical or psychologically meaningful fashion pupils' manuals and teachers' guides previously written for other projects.

Subject Matter

It is not appropriate to speak of the "content of the *Combined Science*

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course." The materials developed by the team have been designed so that more work is suggested than can be covered in five forty-minute periods per week for two years. Teachers using *Combined Science* are expected to produce their own courses from the published ideas, materials and commentaries, although an example of one possible path through the materials is provided. This expectation should be kept firmly in mind when examining Table 5.1, p. 38 which summarizes the subject matter included in the publications.

The material published as *Combined Science* has been selected to emphasize the *unity of approach* of the sciences, without forcing artificial integration of disparate concepts. The exercises and experiments which form the basic portions of *Combined Science* courses have been arranged into ten sections, all but one with a number of subsections. Table 5.1 lists the titles of the sections and subsections.

The expectation that the teacher will exercise professional judgment in selecting the content and order of the materials included in his course does not imply that the ten sections are completely independent. The sections as printed provide an organized development of concepts and related vocabulary: any departure from the broad sequence will require careful planning to avoid omissions and consequent conceptual difficulties.

The following example of the organization of *Combined Science* in one Manchester school illustrates several possible beginning sequences, and, at the same time, shows how some schools avoid apparatus shortages resulting from a number of classes needing the same materials concurrently.

In this school four different pathways through Section One; all following naturally from the opening exhibition and the work on grouping (see Table 5.1), are used. Each route contains the same material, but it is taught in a different order. The work has been broken down into four segments, labelled A-D in the following tabulation. Segment A contains work on measurement and estimation, including temperature; B consists of the subsections "looking more closely at things" and "earthworms;" in C, acidity, alkalinity and methods of purification are studied; and D contains the first subsection, "movement and forces," of Section Two. These segments are taught in the order shown in the four first-year classes in this school:

Class 1:	A	C	D	B
Class 2:	B	C	A	D
Class 3:	C	A	B	D
Class 4:	C	B	D	A

This sequence ensures that only one class at a time requires the more extensive apparatus for the work in segment A. Similar arrangements are

TABLE 5.1

The content of the Nuffield Combined Science materials

(Rearranged from *Nuffield Combined Science Teachers' Guide I* (London: Longman; and Harmondsworth: Penguin, 1970). p. xxii) The listed order of Sections and sub-sections is not necessarily the order in which students will study the material. Teachers are expected to arrange their instructional sequence to suit individual school conditions.

ONE. THE WORLD AROUND US

1. The exhibition-living and never lived
2. Variety of things and grouping
3. Temperatures
4. Estimating and measuring
5. Looking more closely at things
6. Earthworms
7. Making stuff purer
8. Acidity alkalinity

TWO. LOOKING FOR PATTERNS

1. Movement and forces
2. Heating substances
3. Patterns of growth

THREE. HOW LIVING THINGS BEGIN

1. How do living things begin?
2. How do animals breed in water?
3. Breeding in mammals
4. How plants reproduce and make seeds

FOUR. AIR

1. Air is all around us—effects
2. Difference between air and nothing
3. What is in the air?
4. Pressure

FIVE. ELECTRICITY

1. Circuit board work
2. Do all substances allow electricity to flow?
3. Trying to find out about electricity

SIX. WATER

1. Water from different places
2. Finding out about water
3. Animals and plants in water and on land
4. What is water?
5. Can electricity pass through water?

SEVEN. SMALL THINGS

1. How small are small things?
2. Microbes
3. Particles

EIGHT. EARTH

1. Products of the earth
2. Soil
3. Development and growth of eggs and seeds
4. Crude oil
5. Metals from rocks
6. Looking for differences between metals and non-metals
7. Investigation of ores
8. Substances from the sea.

NINE. INSECTS

1. Locusts
2. Large white butterflies
3. Looking at other insects

TEN. ENERGY

1. Investigating the meaning of energy, Heat radiation, Light, Sound

made for other portions of the course used in this school.

The emphasis throughout *Combined Science* is on introducing children to natural phenomena. In general there is little emphasis on explanation in terms of complex scientific models or laws. Occasionally, however, models are introduced to aid explanation of particular sets of observations. For example, in Section Seven it is suggested that children be told "of our belief in the existence of particles, reminding them that it is not possible to investigate everything ourselves. The particulate theory is offered as an idea which helps us to imagine what could have caused the observed effect. [1] The particle model is not given as dogma, but is based on observations of crystals and of Brownian motion. Teachers are also warned to "leave the door open for an attempt to argue the case for other concepts,"[2] even, with a capable class, attempting to explain every experiment from both "particle" and "non-particle" positions.

In the electrical section, the use of an *electron* flow model is avoided, "explanations" being based on the idea of "flow," without formal definition or undue concern about what is flowing or the direction of flow. The emphasis is on observable phenomena in electrical circuits and in contact (static) electricity.

Lists of experiments contained in two subsections of *Combined Science* are given in Table 5.2 p. 40 to indicate the scope of the work. Examples from *Activities* and from the *Teachers' Guide* given later in this Chapter illustrate the depth of treatment expected.

Recommended Teaching Techniques

The strong emphasis in *Combined Science* on using childrens' own firsthand experience is reflected in the number of experiments designed for pupils to undertake in the laboratory. Indeed, as often as possible the child's out-of-school experience is taken as a starting point for gaining additional experience in the laboratory, and opportunities for extending laboratory work outside the school are provided. Outside experiments are also considered to be an important means of encouraging children to explain their science work to their friends and parents. "To show how important we regard them, such experiments should be set as homework."[3]

> The team recommends that children be actively and attentively engaged in laboratory work, . . . [so that they] will develop an appreciation of how to formulate, test, and modify hypotheses . . . Every possible chance should be taken to allow children to think, and suggest things for themselves, to design experiments and activities to test their suggestions and allow them to learn from their mistakes, improving poor techniques by individual, specific comment there and then.[4]

The experience of one teacher who had recently changed to using

TABLE 5.2

Experiments included in two subsections of Combined Science

The page numbers refer to the page in the *Teachers' Guides* where the experiment is discussed. Activities numbers refer to the activity number in the pupils' booklet for the section; experimental procedures for the activities printed in bold type are not provided in the *Teachers' Guides*.

(Photographically reproduced from *Nuffield Combined Science Teachers' Guide I* (London: Longman; and Harmondsworth: Penguin, 1970) p. 313. and from *Nuffield Combined Science Teachers' Guide II* (London: Longman; and Harmondsworth: Penguin, 1970) p. 86)

Subsection 1 **Circuit work – the circuit board**

experiment	title	page	type	activities	
1a	Setting up circuits on the circuit board	316	class experiment		**2**
1b	What happens when thin wires are joined to a battery?	321	class experiment	1, 3, 5 to 15	**4**
1c	Magnets and electricity	324	class experiment		
1d	Making and using a current balance	328	class experiment		**16**
1e	Using ammeters	334	class experiment		
1f	Measuring electricity in different parts of a circuit	340	class experiment	17 to 25	
1g	Different ways of changing the flow of electricity in a circuit	347	class experiment		
1h	Investigating the resistances of wire of various sizes and kinds	349	optional class experiment		
1i	Testing fuses	350	optional class experiment	28 to 33	
1j	Further circuit investigations	351	optional class experiment		
1k	A simple computer	355	optional class experiment		**34**

Subsection 2 **Microbes**

experiment	title	page	type	activities
2	Microbes at work	91	exhibition	
2a	What does yeast need for growth?	93	demonstration experiment	
2b	Fermenting fruit juice	96	class experiment	
2c	What is needed to make bread?	97	class experiment	
2d	Distilling the fermented solution	99	demonstration experiment	
2e	Looking at yeast	101	class experiment	
2f	How can gravy be preserved?	103	demonstration experiment	
2g	Plating	108	demonstration experiment	
2h	Are microbes all around us?	110	class experiment	8 to 31
2i	Looking at bacteria under the microscope	113	class experiment	
2j	Heated and unheated milk	116	class experiment	
2k	Testing the freshness of milk	117	class experiment	
2l	Investigating the bacteria from fresh and sour milk	118	class experiment	
2m	Bacteria and disinfectants	121	class experiment	
2n	Testing the action of penicillin	125	class experiment	

Combined Science with a low ability class in a comprehensive school illustrates some of the advantages of allowing children to extend the activities beyond the point prescribed in the guides. In the Activity "Making Rock Salt Purer," students are asked to evaporate a small drop of saline solution on a microscope slide, and then observe it under low power. One of the less able students in the class did this successfully and, a little later, came up to the teacher and told him, "My sweat has the same sort of salt in it." "How do you know?" "I dried some, and it has the same shape crystals." The teacher reports that this experiment and reasoning was most unexpected in this student, and was the event which convinced him of the utility of guided discovery with students other than the most able.

The experimental approach requires that all classes be taught in the laboratory and that students have direct access to equipment stored, as much as possible, in the laboratory. Students with experience in very open primary school classrooms find this natural. One teacher in an outer suburban school near London reports that children expect unrestricted access to and manipulation of apparatus, regardless of whether or not it is applicable to the ideas being investigated. However, he is very much in favor of open access to materials, with a firmly enforced minimal set of safety rules—avoiding danger to children and excessive risk to apparatus.

When working with Activities, and in some other exercises, children are in need of reassurance that there is not necessarily a "right" answer to every question, and that "sometimes 'anything goes.' "[5] This is particularly true when objects are being grouped (Section One, subsection 4). But "there is no suggestion that the attitude that anything goes should be extended to the manner in which the children make their observation." [6] They are expected to be careful, recording their data with adequate precision. This does not mean an excessive emphasis on accuracy:

> It is good sense, and good science teaching, to allow the need for greater accuracy to develop from the fact that rough measurement will not be good enough in a particular experiment rather than to insist on precision for its own sake.[7]

This practice of initially estimating, and then taking rough measurements, is advocated in the face of the traditional practice in beginning science courses of careful measurement and calculation, for "however skilful and successful the teaching . . . the outcome seems to be technical skill rather than a sense of understanding . . . At a much later stage the techniques can be acquired very quickly."[8]

As well as introducing technical skills when needed it is recommended that technical terms and concepts be provided only when the need arises. For example, although elements and compounds are used in earlier sections these *terms* are not used; the distinction is not made until needed, in the work on the composition of air in Section Four.

Over two-thirds of the experiments described in *Combined Science* are classified by the team as "class experiments," or form part of a circus, (see below). The proportion involving direct student participation is higher than this figure suggests, for some of the experiments designated as "demonstrations" involve most or all of the students in a class at some time, and are not actually staged by the teacher. For example, an experiment on "The force needed to get a mass of one kilogramme moving" involves placing a petri dish containing a 1 kg mass on ball bearings on a glass plate, and then pulling the mass with a Newtonmeter. "The apparatus . . . should be set up, with a suitable notice displayed, so that the children may experience the force at odd times during the lesson."[9] This is classed as a demonstration, although the teacher may not formally use it, and every child may experience the forces involved. Other experiments that are dangerous or involve elaborate equipment are designed as teacher demonstrations.

A circus of experiments contains a number of different experiments related to a common theme. Students move from one activity to another, carry out the required manipulations and observations, and, gradually, develop their ideas about the theme. The introductory circus for Section Four, *Air,* contains seventeen activities, four of which are illustrated in Figs. 5.1, p. 43 and 5.2, p. 44. Although the experiments in this circus illustrate that air occupies space, is required for burning, exerts a pressure, expands when heated, is "spring," and changes when breathed in and out, the experiments are only designed to focus attention on "air." "This is not the time for explanations from the teacher but rather one during which to allow the children to make observations, to encourage their speculations, and to accept their ideas."[10] In any case, some experiments included in the circus defy complete analysis in terms suitable for this age level. During class discussion of this circus "it is likely that unanswered questions will emerge and these can be profitably left as signposts to later work."[11]

Further direct student experience is provided during the "exhibitions" which open Section One, subsection 2 of Section Seven, and Section Eight. The exhibitions are intended to introduce subsequent work and provide a natural lead-in to the other experiments and activities of the course. Although the degree of manipulation expected of the children is different for each exhibition, the introductory comments to the exhibition used to open the course apply in some measure to them all:

The exhibits are to be looked at and handled for acquaintance, to sug-

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FIGURE 5.1

Portion of the instructions for a "circus" included in a Combined Science Activities booklet

Two of the seventeen activities that make up the circus "looking at the effects of air" are reproduced here. Two more are included in Fig. 5.2. The materials for the seventeen activities are placed around the classroom, and students move individually or in small groups from one to another. The experiences are not sequential, so the activities may be undertaken in any order. The intent of a circus is to provide the opportunity for the students to make observations and speculate about causes: circuses are not intended to provide the opportunity for the teacher to make detailed explanations. (Photographically reproduced from *Nuffield Combined Science Activities 4* (London: Longman; and Harmondsworth: Penguin, 1970) p. 6)

5 Light the candle, place the bell jar over the candle and then quickly fit the stopper

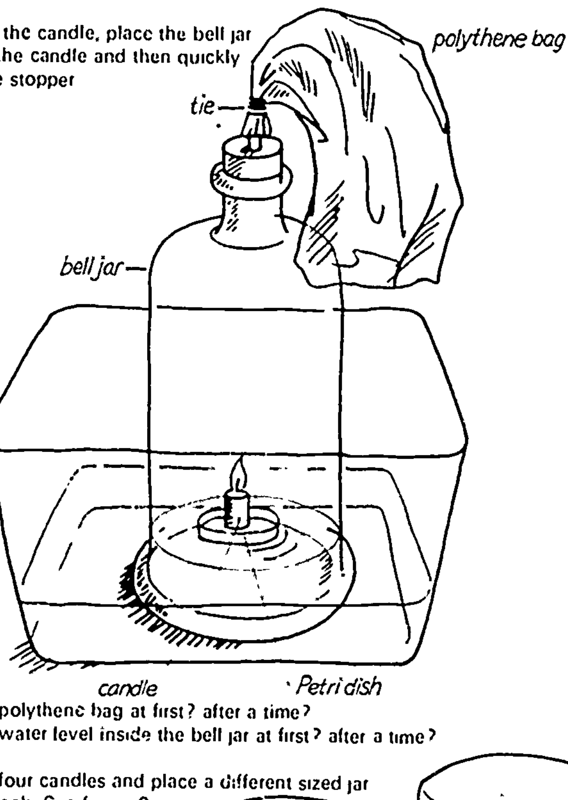


Figure 7

What happens to the polythene bag at first? after a time?
What happens to the water level inside the bell jar at first? after a time?

6 Light four candles and place a different sized jar over each See figure 8.
Time how long each candle burns
Try to explain what happens.
What else do you see?

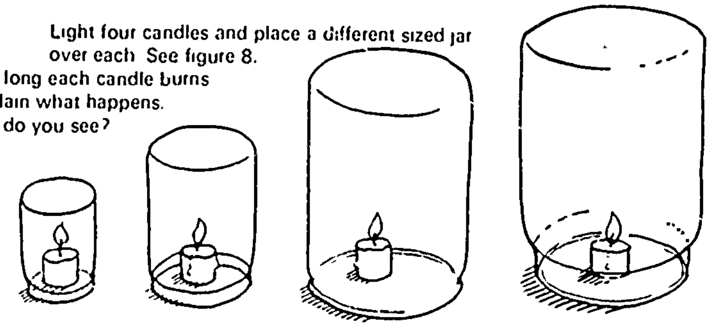


Figure 8

FIGURE 5.2

Additional activities in the "circus" on air

See Fig. 5.1. (Photographically reproduced from *Nuffield Combined Science Activities 4* (London: Longman; and Harmondsworth: Penguin, 1970) p. 10)

13 How much force do you need to pull the disc off in figure 14?
Try different surfaces.
Try it wet and try it dry.
Try it on top of the table, underneath, and on the side
Does it make any difference?
Does the angle at which you pull make any difference?

14 Set up the apparatus shown in figure 15
Open the mouth of each bag.
Balance the beam by moving the wire rider. Don't be too fussy.
Hold the lighted candle about 20 centimetres below the mouth of one of the bags
Do not hold the candle too near – the bag may catch fire.
What happens to the beam?
Take the candle away, now what happens?

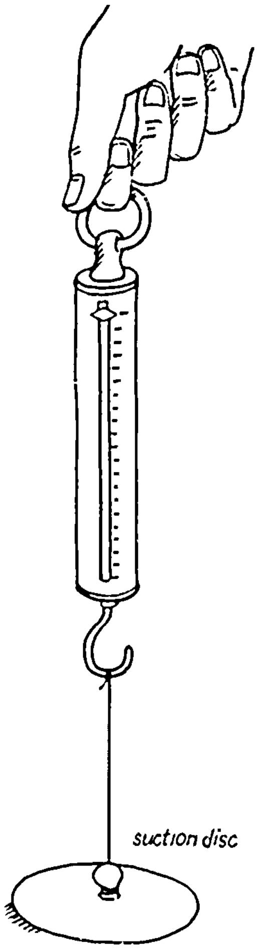


Figure 14

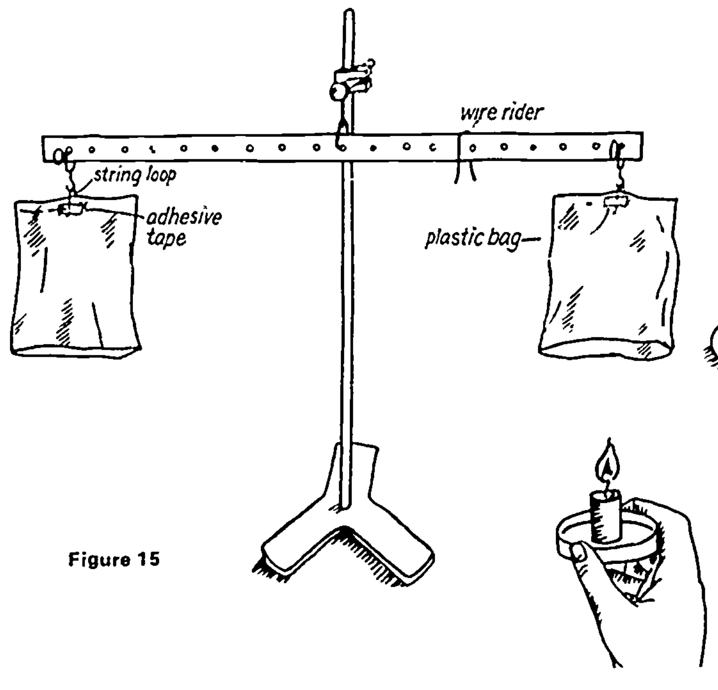


Figure 15

> gest questions and experiments, and to arouse interest—not for note-taking, not for careful tabulation, nor for immediate classification. . . . Much will depend upon the initiative of the individual teacher in managing the exhibition so that the children are not bored on the one hand nor overwhelmed by a mass of material on the other, either of which could lead to a feeling of "what do I do next?" (12)

Specific suggestions for using the exhibitions are given in the *Teachers' Guide*, and include labelling specimens with short instructions or questions, (Feel me; Drop me; Was I found like this or am I manufactured?; Why do I have a hard shell?), and providing opportunities for children to contribute exhibits.

Although not published as part of *Combined Science* many science departments find worksheets useful to increase retention of material, thus helping produce an organized body of knowledge; to facilitate the recording of observations for later class discussion; and to provide support for inexperienced staff, or specialist teachers outside their field of training. Worksheets may be a simple record, e.g., containing a diagram of apparatus; a simple table for results; a table, combined with brief instructions; or a set of sequential instructions with space for recording results. Figure 5.3, p. 46, is part of a worksheet combining sequential instruction and a table for results. As is often the case, the teacher has closely modeled this worksheet on *Teachers' Guide* suggestions.

Material Available

Teachers' Guides. Volumes I and II of the *Combined Science Teachers' Guides* reflect the views of teachers and students in the 35 trial schools. Quotations from trial teachers are interspersed, not as models of expected behavior but to "let teachers speak to teachers and share their experiences."(13)

Very detailed notes on experiments and *Activities*, with some background notes on many of the scientific concepts involved, are included, particularly to help those teachers who have trained, and practiced, as subject specialists.

At the beginning of each section there is a diagram showing the content of the section, its links with other sections, and an estimate of the number of forty-minute periods required for the work. Figure 5.4, p. 47, shows a typical section diagram. Similar diagrams for some subsections outline their content, and indicate possible arrangements of the experiments. The links with other work are not meant as an instruction to include that extension of the topic being considered; they are for the guidance of teachers planning alternate routes through the material.

Each of the subsections, and most of the experiments, is introduced by

FIGURE 5.3

Portion of a teacher-produced worksheet for Combined Science

The worksheet is closely tied to the *Activities* book referred to in point 1 of the worksheet, with some changes of wording, some additional activities designed by the teacher, and spaces for students to record their answers. (Photographically reduced)

C.S.IO. Name.................... Form...........

ESTIMATING AND MEASURING.

1. Using the map on page 12 of "Activities Book 1" :-
   (a) Estimate first by just looking at it, and then measure with a piece of thread, the distance by road between Carmarthen and Fishguard.

   By just looking............ By using thread...................

   (b) Travelling from Monmouth to Carmarthen, which is the shortest route - going via Brecon or Cardiff - and by how much. Estimate first by looking at it, and then measure with thread.

   I estimate that it is shorter going via .... by about .....km.

   Using thread it is shorter going via .... by about .....km.

   (c) Do you find it easy to measure using a piece of thread? ....

   (d) If not, can you suggest a better way of measuring? ....

   ....

   (e) If you have answered (d), and have tried this method of measuring, what do you make the distance between Monmouth and Carmarthen, travelling via Cardiff, to the nearest 10 km? .....km.

2. Estimate the weight of the Castrol tin. ....

3. Estimate the height of your teacher. ....

4. Estimate the length and weight of the objects labelled A, B, C and D around the lab., then measure and weigh with a ruler and lever balance.

Estimated		Measured	
Length	Weight	Length	Weight
A			
B			
C			
D			

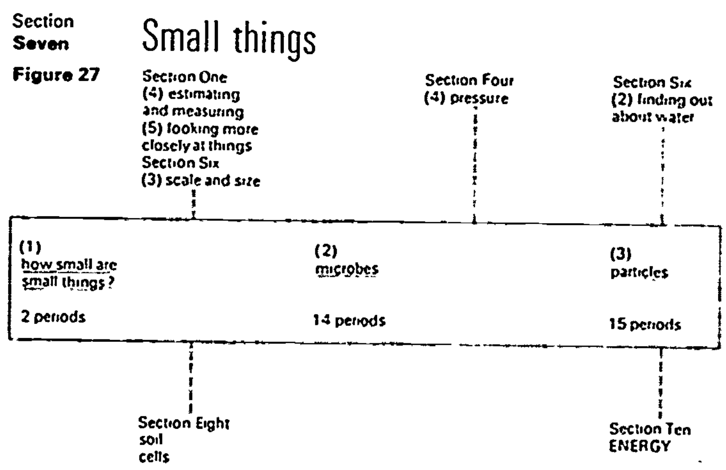
a discussion of general aims, philosophy and content of the succeeding work. The first of the following extracts is taken from the introduction to Section Two, *Looking for Patterns;* the second from the introduction to an experiment in Section Eight:

> Children tend to think of science as consisting of doing exciting things and of finding out something. Older scientists are also concerned with extracting laws or rules to codify things that have been found out. This activity of generalizing, arriving at some law after a variety of experiments or observations, seems to be a very important part of human intellectual growth and yet it may seem strange and difficult to children if we put it to them too early as an essential characteristic of science. (Of course there are other essential characteristics which carry science beyond a mere catalogue of laws or principles into a structure of theory

FIGURE 5.4

Section diagram for Section Seven of Combined Science

A section diagram similar to this introduces the notes for each section of the *Combined Science* materials. Links to other sections are shown by the dashed lines; suggested time allotments are in terms of forty-five minute periods. (Photographically reproduced from *Nuffield Combined Science Teachers' Guide II* (London: Longman; and Harmondsworth: Penguin, 1970) p. 79)



in which both experimental knowledge and imaginative thinking are woven together.) Yet the principle of generalizing is one in which all children engage. When looking at animals they learn to say 'dog' and apply it to many varieties of that animal. They name abstract qualities and then proceed to the abstract thinking which plays such an important part in man's intellectual activities. Patterns and constancies are lifelines in the complexity of the world around us and help avert a feeling of anxiety. If the events of each day were so very different from the ones that went before, life would soon become very difficult. Our complex, rational life would be almost impossible. If we, ourselves, reflect on the laws of science, we find that many of them contain the word "constant" or its equivalents, and most of the others can be reworded to contain it. This is one of our main activities in science, to look for constancy, to look for things or characteristics of events that repeat, always giving the same answer in the same circumstances. Such activity is also beneficial in that it takes the emphasis from a single experiment proving that an idea is right, and shifts it to showing that an idea is not wrong. And this, with repeated experiment, may approach a higher degree of certainty.[14]

This experiment [Extracting copper from solution] explores the possibility of obtaining a metal from a solution. If children have experience of electricity, they may suggest passing electricity through the solution (see Sections Five and Six). They may know that dipping iron into the solution results in a deposit of copper on the iron. (The deposit of copper is a result of the substitution of copper for iron.)

Starting from cuprite the first problem is to get it into solution. Experiments show that water will not do, so acid is used—M sulphuric acid solution is suitable.

There is no need to discuss all of this with the children in advance. Their own experience should lead them to an appreciation of the problems but they can be guided towards possible solutions by a helpful word here and there.[15]

Details of most experiments are also contained in the *Teachers' Guides*. Figure 5.5, p. 49, reproduces a typical arrangement. In addition to details of preparation for the experiment, with apparatus lists based on a class of 32 students, the text contains the experimental procedure; specimen dialogue or commentary; comments and possible extensions or modifications; and quotations from trial teachers.

Reference to the third volume of the *Teachers' Guide* is made in the comments on most experiments. It contains general hints in the use of apparatus, experimental techniques, teaching procedure, classroom activities, visual aids, and other points on teaching *Combined Science*. There is also a section listing apparatus requirements, recommending methods of storage, and, where possible, providing methods of constructing alternate versions in the school. Apparatus construction sheets are provided for some of these items. There is also a catalogue of suggested teaching aids for each section, and an appendix on the mathematics involved in the experiments, especially the statistical presentation of results. The use of a "statistics frame" is recommended for the tabulation of class results (Fig. 5.6, p. 50).

FIGURE 5.5

Sample page from the Combined Science Teachers' Guide

This page from the *Teachers' Guide* illustrates the method used to provide information for teachers. The apparatus requirements are based on a class of 32 pupils. Following the experimental procedure some suggested comments and questions are listed (indented to distinguish them from the procedure); comments and possible modifications noted (indicated by the sign "—" before the line); and quotations (enclosed in single quotation marks) from trial teachers reproduced to enable "teachers to speak to teachers." (Photographically reduced from *Nuffield Combined Science Teachers' Guide II* (London: Longmans; and Harmondsworth: Penguin, 1970), p. 15)

2d   Do plants lose water?

Class experiment

item no	requirements
200	1 balance direct reading
42	4 balances lever arm dual range 250g/1000g
543 1	16 felt tipped pens
316	16 Petri dishes, non-sterile
	48 jam jars
	selection of vegetables and fruits, such as, cabbage leaves, lettuce leaves potatoes carrots apples, and oranges
	sprays of leaves and cut flowers

Direct reading and lever arm balances should be available the children select whichever seems more appropriate

The sprays of leaves vegetables, and fruits should be fresh

Discuss the design of an experiment with the children to find out whether sprays of leaves change in mass when they are left. Tell them to weigh:
A jam jar containing a spray of leaves.
A jam jar containing a spray of leaves and a 5cm depth of water.
A jam jar containing a 5cm depth of water.
A Petri dish containing a piece of fruit or vegetable.

After recording the masses, the jars and Petri dish are labelled and put on one side. Different groups could leave their jam jars in different conditions, such as on a window-sill, in a dark corner of the room, near a radiator, in a cool place, or in the dark.

The jars and dishes should be weighed at intervals.

> What happens when a spray of leaves is left without water?
> What happens if the spray of leaves is in water?
> What happens to the fruit and vegetables?
> What do you think is being lost? How could you find out if you are right?
> About how much water does lettuce contain?
> Do some things lose water quicker than others? Why?

– Children may suggest accelerating the loss of water by raising the temperature. This
– could be investigated by putting the Petri dishes containing fruit or vegetables in an
– incubator

– 'We put some lettuce leaves in a plastic bag which was tied at the neck and noticed
– moisture inside the bag. The moisture was found to contain water by testing with
– blue cobalt chloride paper.'

– 'We found a loss of $2cm^3$ of water per leaf per day in dry hot weather. The number
– of leaves on a tree was estimated and we decided that the tree lost $90\ 000cm^3$
– of water per day.'

FIGURE 5.6

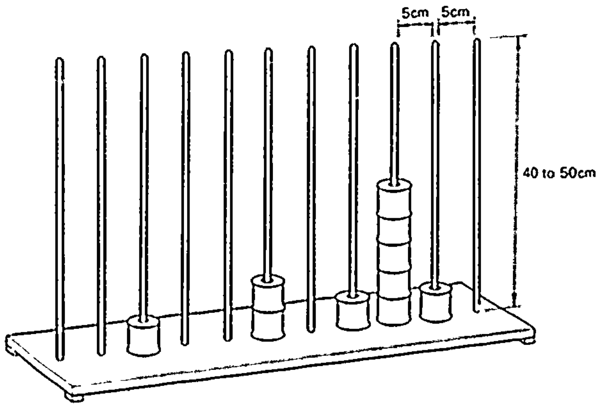
Portion of a Construction Sheet for Statistics Frame

The statistics frame is recommended for use in recording data from class experiments, producing a histogram presentation when all data are entered on the frame. There are also construction sheets for "component testers" (testing electrical components of circuit boards), a "pooter" (for collecting small insects), a "wormery," a locust cage, a mammal cage, a butterfly pairing cage, and a plant propogator. (Photographically reduced from *Nuffield Combined Science Teachers' Guide III* (London: Longman; and Harmondsworth: Penguin, 1970) p. 214)

Statistics frame

This item is used on many occasions in Combined Science and should be designed so that it may be used in conjunction with the plastic safety screen, so that a record of the plot may be made directly onto the screen (or on a plastic film clipped to the screen). Dimensions and numbers of cylinders and rods are not vitally important but those shown below are adequate and convenient.

Figure 1



Materials

1	**baseboard:** wood which will not warp, 60 to 80cm long, 15cm wide, 2 to 3cm thick. Length will depend on number of vertical rods used.
about 100	**cylinders:** metal, plastic, or wood, about 2·5cm diameter, about 2·5cm long, drilled with holes to be a loose fit on the vertical rods. Used cotton reels are suitable.
4	**feet** plastic or rubber
11 to 15	**rods:** metal, plastic, or wood, about 0·5cm diameter, 40 to 50cm long.

Construction

The baseboard should be drilled with an appropriate number of holes for the vertical rods to fit tightly. Some teachers may prefer to use threaded rod and secure the rods to the baseboards with nuts and washers. Others may be able to thread the lower ends of the rods to achieve the same result.

The surface of the baseboard should be treated so that the numbers may easily be written on and rubbed off. A felt tipped pen could be used.
The cylinders should be a loose fit on the rods so that they slide up and down easily.

Activities Books. A booklet of *Activities* for pupils is available for each section. These are not textbooks, but are intended to be used to "start children thinking about a new piece of work, to give them ideas of things to find out to do, to extend work due in the laboratory, to give some background to a piece of work, to take the place of class discussion, to give practical instructions both for home and laboratory-based experiments, and to give visual stimulation and reinforcement."(16) Details of all circus experiments are included (See Figs. 5.2 and 5.3 for examples), and for many of the other experiments as well. Fig. 5.7, p. 52, is a sample page from an *Activities* book illustrating the type of extension question used and background information provided.

To enable students to "forge ahead without the delay of waiting for teacher's instructions"(17) a set of reference sheets indicating how to use apparatus such as burners, microscopes, and measuring devices is included in *Activities Pack I*. Fig. 5.8, p. 53, is a sample page.

Film Loops. A series of nineteen film loops (See bibliography for titles) has been produced to provide indirect experience of events impossible to arrange in the laboratory, or to provide a link with the industrial world. Some loops are designed to introduce techniques, for teachers *(African Clawed Toad—Injections and Pairing)* or students *(Male Rat—Finding the Reproductive System; Female Rat—Finding the Reproductive System).*

Current Work

Although the *Combined Science* project has published all of its materials, a continuation project has been set up to produce a guide to using *Combined Science* in the middle schools being established by many LEAs. No materials have resulted from this project to date.

ERIC

FIGURE 5.7

Sample page from a Combined Science Activities Booklet

Note the use of questions to guide students' thinking. (Photographically reproduced from *Nuffield Combined Science Activities 4* (London: Longman; and Harmondsworth: Penguin, 1970) p. 20)

33 What makes the syringes used in the copper heating experiment airtight?

34 Can you devise a piece of apparatus to collect several bottles of inactive gas from the air using the heating of copper?

35 Imagine you are given a solution which absorbs active gas but not inactive gas.
How would you try to find out the fraction of active gas in the air?

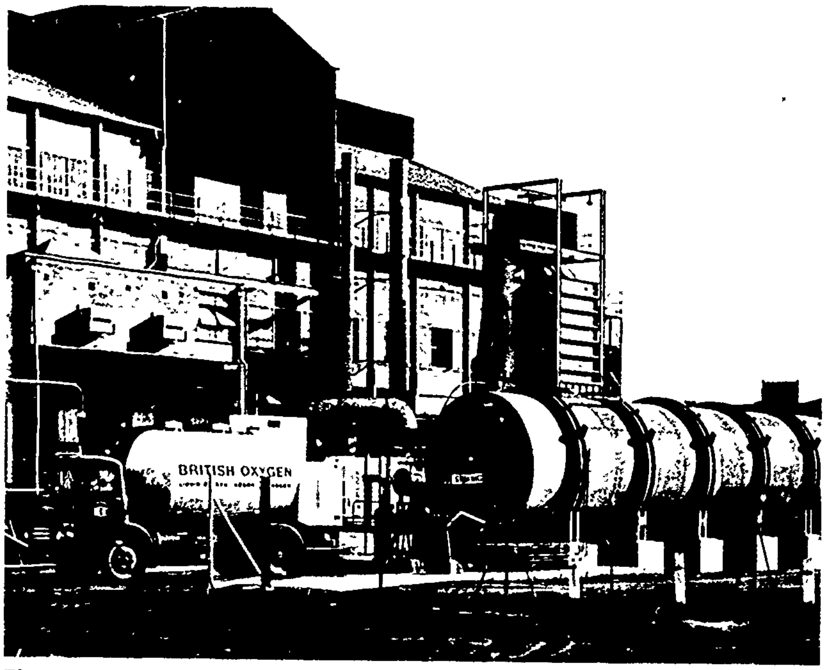


Figure 27

36 Gas in the transporter would take up over 800 times as much space as an equal mass of liquid (see figure 27).
Some gas must be lost on the way so why don't the manufacturers carry gas in sealed tanks?
What do you think is in the cylinder in the laboratory – liquid oxygen or oxygen gas?
Why does oxygen gas come out when you open the cylinder valve?

FIGURE 5.8

Sample page from Combined Science Reference Sheets

Reference sheets provide students with information about the following techniques: use of hand lenses, microscopes, burners, balances, meter rules, graduated cylinders, and electrical meters. They are intended to free the child from dependence on the teacher for instruction in routine techniques. (Photographically reduced from *Nuffield Combined Science Reference Sheets* (London: Longman; and Harmondsworth: Penguin, 1970) p. 22)

Measuring

Measuring length

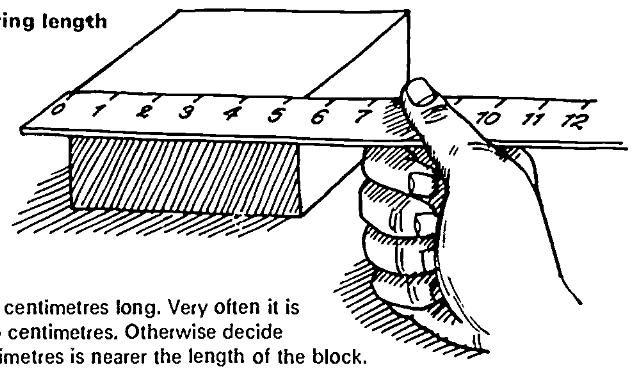


Figure 25

This block is just over 5 centimetres long. Very often it is close enough to call it 5 centimetres. Otherwise decide whether 5·0 or 5·5 centimetres is nearer the length of the block.

Measuring volume

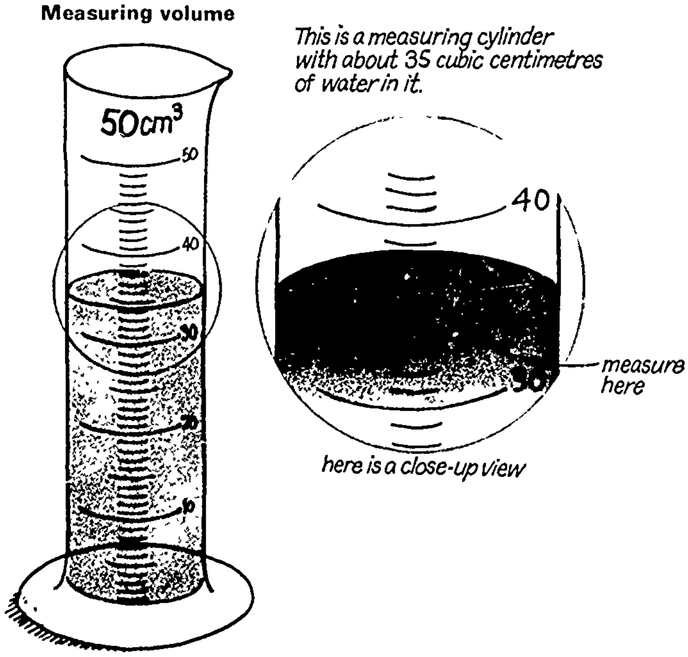


Figure 26

The measuring cylinder must be upright – not tilting over. Why is that?

ERIC Full Text Provided by ERIC

6

NUFFIELD SECONDARY SCIENCE

Nuffield Secondary Science was designed to be a "quarry from which teachers select suitable material to build coherent courses."[1] This is quite different from Scottish Integrated Science, with its carefully structured syllabus, and from *Combined Science*, which, although teachers are expected to exercise their professional judgement concerning details of content and order, is written in a possible teaching sequence.

This arrangement reflects the history of *Secondary Science*, and the population at which it is aimed. *Secondary Science* is based upon a Schools Council Working Paper[2] concerned with the science education of pupils of average or below average ability aged from 13 to 16. The Working Paper recommended that future science courses have significance for pupils as adolescents and be "concerned with realistic matters of adult stature."[3]

An important consequence of the "adult" criterion is that "the problem of dealing with personal, social and moral implications when they arise in connection with science will have to be faced. No treatment of science with both boys and girls can, in fact, claim to be realistic or of adult stature if it excludes or sheers away from issues of this kind, and much that may be of vital interest to the pupils is likely to be in this category."[4]

The Working Paper suggested that there were certain major themes of science with which all these pupils should be acquainted. However, variation in the emphasis given to each theme is to be expected in courses prepared for different circumstances and pupils. All courses provided should, it was emphasized, have some coherent pattern.

The Working Paper included suggestions for eight themes, and, for two of the. , indicated possible fields of study and topics to illustrate how a course meeting the suggested criteria could be developed. Some possible pupil activities for one theme were listed to indicate relevant teaching methods.

Secondary Science is firmly based upon the principles of the Working Paper, except that the target population has been extended to include all those unlikely to be taking science examinations at the **O** level of the

General Certificate of Education. Some of these pupils will probably attempt O levels in other subjects. Consequently, students using courses derived from *Secondary Science* will be mainly drawn from the lower 75 percent of the ability range of the population aged 13-16.

Aims

Secondary Science attempts to provide pupils with the "opportunity to understand something of the scientific background and implications of economic, social and moral problems which concern us all," and to equip them for everyday life which brings "the need to solve problems, to predict the consequences of actions, and to evaluate the assertions of politicians, advertisers, or scientists." It is assumed throughout that "the attitudes of mind and habits of thought needed [to achieve these long term aims] can be encouraged within the science lesson."[5]

The immediate objectives in *Secondary Science* lessons are to provide opportunity for, and encouragement of, accurate observation, deduction of generalizations, inference from concepts or generalizations, design of simple experiments, and formation of hypotheses. In addition the opportunity is taken to improve verbal fluency, literacy and numeracy, and to encourage self-discipline and responsibility for organization of work.

Only "significant" content is recommended to assist in the attainment of these general aims and objectives. The *Teachers' Guide* repeatedly emphasizes that "significance" should be a major criterion for judging whether activities are to be used in any *Secondary Science* course, as it was in deciding whether to include a topic in the published themes. "Teaching science in terms of significance means that we must continually be aware of the everyday life of our pupils, whether in sports, shopping, running the home, repairing cars, watching television, or in whatever happens to be the latest craze. We must continually relate what is happening in the laboratory to the real life situation."[6] Each new aspect of the science content should be based on pupils' "real-world" experience.

"Significance" is also related to such questions as "How fast are we using up our available source of energy? . . . Does it matter if a nature reserve is destroyed?"[7] These are fundamental problems, and although they may not concern students when in school, indeed they may not even be aware of them, the problems are likely to be of considerable significance within a few years of students leaving school.

The preceding examples of problems of social concern indicate that the *Secondary Science* emphasis on "significance to the pupils" does not imply that the students should directly choose to study what is of interest to them at any particular time. Although some teachers do plan the particular course they are going to follow by consultation with the pupils concerned, this is not a necessary prerequisite for "significance." The *Teachers' Guide* comments that even though it is impossible to be certain what will eventually prove to be significant for each individual pupil, it is the teacher's responsibility to make a selection of material he feels is suited to his particular classes. He is helped in this choice by the feedback from trial schools; material which trial teachers found was not of significance to their students is not included in the *Secondary Science* publications.

Themes

The eight themes suggested in the Working Paper have been developed as the *Secondary Science* source books. The content of these Themes is indicated in Table 6.1, p. 57, where the title of each Theme, and of each constituent Field and Section, is listed. The Themes, and the Fields within them, are generally independent, although with numerous links and overlapping areas that teachers can use to provide coherence in the courses they produce. Themes rarely require work from another Theme as a prerequisite. The work on electronics in Field 5.4 is an exception;[8] it requires an adequate background knowledge of alternating current, obtainable from Field 4.3. In other cases, Fields in different Themes may be concerned with the same concepts, and may use identical investigations. This independence means that no importance should be given to the numerical order of the Themes, or of the Fields within each Theme, except that the first Field is a necessary introduction to the work of some Themes. The numbers are used primarily as convenient references to sections of *Secondary Science*.

Within the text for each theme the long-or short-term objectives of each piece of work are discussed. These are not explicitly stated in terms of behavioral objectives, but general discussions in the section introductions and in the rationale for the suggested investigations show the teacher the purposes for which the material has been designed. The following extract from the introduction to Field 4.3 illustrates the approach:

> The important part played by electricity in the lives of civilized communities in the twentieth century will be obvious to the pupils. In field of study 4.3 we are concerned with the different ways in which electrical energy is used in our everyday lives and one aim in this Field of study is to illustrate the versatility of electricity—the ease with which it can be converted into a number of other forms of energy and its great value as a means of transferring energy from one place to another. Through the investigations suggested, the pupils should be able to understand the functioning of most of the electrical apparatus they are likely to

TABLE 6.1

The content of the Secondary Science Themes

The entries in the table have been assembled from the lists of contents in each Theme and the summary table for each Field of the *Secondary Science* publications.

THEME	FIELD	SECTION
1. Interdependence of living things	1.1 Environmental studies, classification, and identification	1.11 Investigations in an aquatic habitat 1.12 Investigations in a non-aquatic habitat 1.13 Field work for schools in built-up areas 1.14 Soil
	1.2 Basic exchanges	1.21 Water exchange 1.22 Carbon and oxygen exchange 1.23 Energy exchange 1.24 Nitrogen exchange
	1.3 Animal and plant growth: population studies	1.31 Growth investigations 1.32 Population studies
	1.4 Colonization; disease, pest, and weed control	1.41 Colonization 1.42 Disease, pest, and weed control
2. Continuity of life	2.1 Animal and plant reproduction and propogation	2.11 Introductory work on life cycles 2.12 Aspects of life cycles 2.13 The importance to man of a knowledge of life cycles
	2.2 Inheritance	2.21 Variations in plants and animals 2.22 What are the influences on plant growth? 2.23 Ancestry and variability 2.24 Why am I like I am? 2.25 The mechanism of inheritance 2.26 How useful is man's knowledge of inheritance?

THEME	FIELD	SECTION
	2.3 The process of evolution	2.31 A review of the evolution of modern breeds of animals and plants
		2.32 Human physical evolution. Has man gradually changed?
		2.33 Geological evidence about past populations
		2.34 An examination of some animal and plant populations
		2.35 Variation, adaptation, and predation.
		2.36 Micro-evolution in action
		2.37 Other phenomena
		2.38 To what extent is man like other animals?
		2.39 Man's effect upon evolution
3. Biology of man	3.1 Physical activity	3.11 The experience of physical activity
		3.12 Gaseous exchange
		3.13 Fuel
		3.14 Transport
		3.15 Heat production and temperature regulation
		3.16 The engines and machinery
		3.17 Growth and repair
		3.18 Water balance and waste
	3.2 The human life cycle: reproduction, growth, and development	3.21 Conception to birth
		3.22 Childhood
		3.23 Physical development during adolescence
		3.24 Changes in behaviour at adolescence
		3.25 Maturity and ageing
	3.3 Health and hygiene	3.31 Micro-organisms and food
		3.32 The body's defences
		3.33 When the defences are breached
	3.4 Senses, behaviour, and learning	3.41 The senses
		3.42 Perception
		3.43 Simple behaviour—response to a stimulus
		3.44 Human behavior
		3.45 Motivation
		3.46 Attitudes
		3.47 Personality
		3.48 Substances influencing behaviour

THEME	FIELD	SECTION
	3.5 Man in the world: control of the environment	3.51 Mans' need for food
		3.52 Water and sewage
		3.53 Clean air
		3.54 Controlling the temperature
		3.55 Energy
		3.56 Other people
4. Harnessing energy	4.1 Energy in action	4.11 Energy conversion
		4.12 Energy and movement
		4.13 Energy and changes in materials
	4.2 Man's energy; his physical limitations and the use of machines	4.21 Exerting and measuring forces
		4.22 Exerting forces by simple machines
		4.23 Doing work in simple situations
		4.24 Physiological effects of doing work
		4.25 The power output of the human body
		4.26 Power of engines and motors
		4.27 Working through machines
	4.3 Electrical transmission of energy	4.31 Introductory investigations
		4.32 The versatility of electricity
		4.33 The behaviour of simple d.c. circuits
		4.34 The use of alternating current
		4.35 Electricity and movement, motors and dynamos
		4.36 Converting a.c. and d.c.
	4.4 Problems of bringing energy to bear	4.41 Heat as a form of energy
		4.42 Heat
		4.43 Looking at changes
		4.44 The efficient use of fuels

THEME	FIELD	SECTION
5. Extension of sense perception	5.1 Human limitations—extending the range of sense perception	5.11 Introduction
	5.2 Hearing and the nature of sound	5.21 Introductory experiences 5.22 The characteristics of sound 5.23 The transmission of sound 5.24 The speed of sound in air 5.25 Sound as the raw material of music 5.26 Noise and acoustics 5.27 Sound reproduction and recording
	5.3 Seeing and the nature of light	5.31 The camera 5.32 Illumination 5.33 Using lenses and mirrors—optical instruments 5.34 Colour and its effects 5.35 The nature of light
	5.4 Artificial aids to communication and recording	5.41 The telephone 5.42 Radio 5.43 The transistor as a switch. Simple switching circuits 5.44 The c.r.o., radar, and television
6. Movement	6.1 Transport	6.11 Getting things moving 6.12 Things in motion 6.13 The internal combustion engine 6.14 Stopping a moving object 6.15 Air transport 6.16 Falling and going round in circles 6.17 Vibrations, resonance, and waves
	6.2 Natural movements of living things	6.21 Movement for a purpose 6.22 Movement of animals' limbs 6.23 Balancing 6.24 Further discussion of angular momentum 6.25 Walking, running, and jumping 6.26 Projectiles 6.27 Other ways of moving 6.28 Flying 6.29 Swimming

THEME	FIELD	SECTION
7. Using materials	7.1 Introduction: collection, classification, and preliminary investigations	7.11 Classification
		7.12 Investigating the structure of matter
	7.2 Metals and alloys	7.21 Introduction
		7.22 Metals and their sources: winning metals from the earth
		7.23 Effects of heat on metals
		7.24 Effects of environment on metals: corrosion and protection
		7.25 How can metals be protected?
		7.26 Mechanical properties of metals
	7.3 Fuels	7.31 Dangers and precautions
		7.32 Burning some materials
		7.33 The origin and manufacture of fuels
		7.34 Igniting fuels
		7.35 Ash, and air pollution
		7.36 Storing and delivering gas
		7.37 Stopping fuels from burning
		7.38 Rocket fuels
		7.39 When will all our fuels be used up?
	7.4 Synthetic materials and natural products	7.41A Traditional and modern building materials
		7.42A Strength and hardness of materials
		7.43A Porosity of building materials
		7.44A The effects of heat on materials
		7.45A Effects of environment on materials
		7.41B Washing: soaps and soapless detergents
		7.42B Soaps and soapless detergents compared
		7.43B Other cleaning materials: bleaches, disinfectants, and solvents
		7.44B Emulsions: cosmetics, polishes, and paints
		7.41C Fibres, fabrics, and sources of textiles
		7.42C Porosity of textile materials
		7.43C Washing and cleaning textiles
		7.44C Thermal stability of fabrics
		7.45C Strength, elasticity, and water resistance
		7.46C Colour: dyeing fabrics

THEME	FIELD	SECTION
	7.5 Radioactive materials	7.51 Introduction to radioactivity
		7.52 Radiation and ionization
		7.53 Activity, hazards, and protection
		7.54 Life of radioactive substances: the nature of the radiation
		7.55 The uses of radioactive materials
		7.56 Biological effects of ionizing radiation
8. The Earth and its place in the Universe	8.1 Getting away from the Earth	8.11 How do we get away from the Earth?
		8.12 Orbits
		8.13 Getting into orbit
		8.14 How does a satellite keep going in orbit?
		8.15 Why are modern rockets so large?
	8.2 The Solar System and beyond	8.21 The Earth's environment
		8.22 The Earth in space
		8.23 The Moon
		8.24 The other members of the Solar System
		8.25 The Sun and other stars
		8.26 Man in space
	8.3 The weather	8.31 The atmosphere
		8.32 What are the factors which help to cause weather phenomena?
		8.33 The sequence of weather patterns
		8.34 The effects of weather on our everyday lives
	8.4 The Earth's crust	8.41 Basic questions and information
		8.42 Examples of teaching schemes
		8.43 Suggestions for follow-up work

> use at home or at work and with this understanding they should develop an appreciation of the safety rules which must be observed in handling apparatus.
>
> A consideration of electrical safety is of considerable importance, not only in the laboratory situation, but in homes, offices, and factories. For this reason, electrical safety has been integrated with the work throughout. The pupils should not be led to regard electricity as essentially dangerous, but they should always be aware that it is a form of energy which is particularly versatile in its uses and easy to handle, and that accidents usually occur through ignorance or carelessness. Mains electricity should always be treated with respect and the pupils left in no doubt about the fatal results which can arise if equipment is mishandled. The importance of earthing appliances, and of replacing faulty or damaged wiring and components immediately when the fault is detected, should be emphasized. The dangers, too, of having wiring and installation carried out by someone not fully qualified to do this work need to be strongly stressed.[9]

Summary tables at the beginning of each Field also allow the inference of the aims of that work. Table 6.2, p. 64, reproduces part of the summary table for Field 6.1. (Note that alternate methods for developing the relationships between force, mass, and acceleration are suggested in Section 6.12. One uses ticker-timers, the other timing clocks, to measure the time for ballistic carts to travel known distances.)

Pupil experiments and teacher demonstrations are suggested in each Theme, providing sufficient detail so that a teacher trained as a specialist in one field will readily be able to use the work from different disciplines. In many cases sample worksheets are illustrated. The experimental procedures for each group of activities are supplemented by suggestions for discussion topics, for techniques of consolidation in which the teacher ensures that the objectives have been attained, and background information to give teachers the necessary basic knowledge before they refer to other sources of information. Figure 6.1, p. 65, illustrates the type of advice on experimental procedures that is given to teachers.

The follo ·ing extract from Theme 3 follows work in Section 3.52, *Water and Sewage*. It is typical of the manner in which discussion points are suggested to teachers:

> Discussion points
> 1. If we have an adequate rainfall, why do we need artificial reservoirs?
> 2. Is it right for valleys to be flooded to store water for people hundreds of miles away?
> 3. Dental decay is known to be much less common in areas where there is normally a high fluoride content in the drinking water. Is it right to increase artificially the concentration of fluoride in drinking water?
> 4. Should people be allowed to use reservoirs for bathing, picnicking, sailing, water skiing, and fishing? Some water authorities forbid these

TABLE 6.2

Portion of the Summary Table for Field 6.1 of Secondary Science

SECTION	MATTERS EXPLORED
6.11	**Getting things moving**
	I Experience of motive forces
	II Applying forces in 'real' situations
	III The effect of reducing friction
	IV Inertia
	V Mass and weight
6.12	**Things in motion**
	Method A
	I Learning to use ticker-timers
	II Keeping things moving
	III Making things go faster: force and acceleration
	IV How can we get the same acceleration for trolleys of different mass?
	Method B
	II Keeping things moving
	III Making things go faster: force and acceleration
	IV How can we get the same acceleration for trolleys of different mass?
6.13	**The internal combustion engine**
	I Examining model engines
6.14	**Stopping a moving object**
	I Friction and resistance to movement
	II Bringing moving things to rest
	III Braking distance and speed on a bicycle
	IV The relationship between the speed and the stopping distance of a sliding object
	V Collisions
	VI Safety in cars
6.15	**Air transport**
	I The movement of aerial 'plankton'
	II Streamline flow
	III Measuring lift and drag on an aerofoil
	IV Propulsion
	V Stability and control
6.16	**Falling and going round in circles**
	I Motion on an inclined plane
	II Falling
	III Going round in circles
	IV Apparent weightlessness

Roman numerals are used to label student investigations described in the Theme texts.

(Source: W. Richardson and J. K. Tollyfield, *Nuffield Secondary Science: Theme 6, Movement* (London: Longman, 1971), p. 2)

FIGURE 6.1

Portion of the instructions for an investigation in Secondary Science

(Photographically reproduced from Dennis Fox, *Nuffield Secondary Science: Theme 3, Biology of Man* (London: Longman, 1971). pp. 14-15)

IV
What is the power output while cycling?

The bicycle ergometer used in this section can either be bought from a supplier or made in the school from an old bicycle. Details are given in the *Apparatus guide*.

The wheel of the manufactured machine is exactly 1 metre in circumference and is equipped with a revolution counter. If the home made machine does not have a revolution counter it will be easier to count pedal revolutions than wheel revolutions. The method of working with the two versions will thus vary slightly.

1. Home made machine

Figure 2 shows the arrangement of a rope brake and two dynamometers.
When the wheel is stationary, $F_1 = F_2$. When the wheel is turning, F_1 will be less than F_2. The frictional resistance, F_3, at the circumference of the wheel is equal to $F_2 - F_1$.

The force, F_3, in newtons, at the circumference of the wheel is measured by taking the difference in the readings of the two dynamometers as the wheel is turning. This force can be adjusted by altering the tension on the rope and should be adjusted to 20 or 30 newtons according to the size of the pupil. The distance, d, moved by a point on the circumference of the wheel during one *pedal* revolution is measured in metres.

The work in joules done per pedal revolution is force (measured in newtons) × the distance (in metres) moved by the point on the wheel:

$$W = F_3 \times d$$

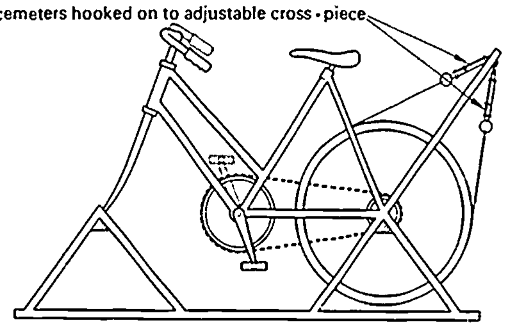
The work done will be of the order of 100 joules. The subject pedals as quickly as possible and the number of pedal revolutions, n, in 20 seconds is counted.

Work done in 20 seconds is $F_3 \times d \times n$ joules

so the work done in 1 second is $\frac{F_3 \times d \times n}{20}$ joules

The power output $= \frac{F_3 \times d \times n}{20}$ watts

Figure 2 Arrangement for home-made bicycle ergometer side elevation



WORKSHEET EXAMPLES

1. Take the readings of both forcemeters before you sit on the bicycle.
Forcemeter *a* ...... newtons
Forcemeter *b* ...... newtons

2. Sit on the bicycle and pedal as quickly as possible.
What are the forcemeter readings now?
a ...... newtons
b ...... newtons

3. How much force did you exert on the rope? ...... newtons

4. Mark a point on the wheel and find out how far it moves when you turn the pedals *once*.
Distance is ...... metres

5. How much work did you do when you turned the pedals once? ...... joules

6. How many times can you turn the pedals in 20 seconds? ......

7. How much work did you do in 20 seconds? ...... joules

8. How much power did you develop? ...... watts activities; others allow them after establishing proper controls and safeguards.

5. Does it matter if the rivers become so polluted that nothing can live in them?[10]

In many cases suggested techniques of consolidation include conducting experiments that reinforce the point made in preceding work, or emphasizing the technological application of the principles elucidated. In other cases, however, the consolidation method suggested involves a discussion of related problems, some applied, and others relatively academic. The extract below concludes a series of suggested experiments, investigations and discussions on circular motion:

Discussion and consolidation

1. There is some danger of a fast rotating wheel, such as a grinding wheel, flying to pieces. Why is this?
2. When a car goes round a corner, what supplies the force acting towards the centre? (Force between the tyre and the road.)
3. One of the popular rides at the fair is the 'chair-o-plane' type of roundabout where the seats swing outwards as it goes round. How is the force acting towards the centre supplied in this case?
4. What are centrifuges used for, and how can their action be described? Is this the same action as a spin dryer? Finally the work can return to a discussion of Earth satellites.[11]

Pupil Activities

Involvement of pupils in experiments is the essential core of the Theme texts. The "spirit of the work should be one of investigation in which first-hand observation and experiment provide essential opportunities for acting and thinking scientifically.[12] Although it is intended that pupils be given the stimulus to understanding that results from the "emotional and intellectual impact of discovering something, often completely unexpected, from one's own efforts,"[13] the expectation that children "discover" *all* their science is seen as "quite unrealistic." Most suggested investigations are, therefore, "genuine as far as the pupil is concerned, but are structured by the teacher in such a way that the pupil is usually successful in the sense that he has a clear answer to a question and does not feel he has wasted time."[14] This is particularly true in some complex sections where "entirely free investigations are unlikely to be rewarding to the pupils and may cause much frustration."[15] The work on electronics in Field 5.4, *Artificial Aids to Communication,* is a prime example.

Open-ended studies that students suggest and design cause problems for similar reasons. In the Themes, possibilities for open-ended work suggested to teachers normally consist of relatively simple biological investigations of problems students are likely to raise. Teachers are also cautioned to "avoid suggesting open-ended investigations that lack significance."[16]

There is some evidence suggesting that students using courses which emphasize direct pupil experimentation tend to believe only those scientific principles they have discovered or demonstrated for themselves.[17] This raises some dangers for science instruction, for, after they leave school, most students are unlikely to conduct another experiment. Even for those who become scientists, there is a necessary reliance on data of others. The way in which *Secondary Science* uses secondhand data, particularly in Fields which develop concepts not amenable to direct pupil experimentation, should minimize extreme scepticism, but encourage rational judgment.

Teachers are advised that in using evidence derived from other sources pupils should be encouraged to ask themselves:

> Does this statement seem likely?
>
> Does it fit in with our own experience?
>
> Was an experiment done and, if so, how was it done?
>
> Could we check the results?
>
> If untrue statements have been made, why do we think this might have happened?[18]
>
> The pupils should come to realize that evidence at second hand consists of the results of other people's investigations and experiences. Where possible, such evidence should be related to the pupils' observations . . . They should be expected to try to decide for themselves how far to trust any relevant data and the conclusions to which they lead. They should certainly realize that data which give the answer 'no' to an idea are as important as data which support the idea, and that often the data available are not enough to give a conclusive answer.[19]

An example of a set of second hand data is reproduced in Fig. 6.2, p. 69. The sample worksheet accompanying these data relates the butterfat variations to another suggested exercise where students determine butterfat content of commercial milk samples, to economic factors in farming, and to some legal requirements for retail milk.

At the end of most Fields there is an extensive reference list of books, pamphlets, films, film loops and, in some cases, transparencies. These materials are suitable for teacher or student reference, as sources of secondhand data, or as teaching aids. Many of the recommended film loops and transparency sets were specially prepared for *Secondary Science* or one of the other Nuffield Foundation Science Teaching Project courses. Other suitable film material is also recommended.

FIGURE 6.2

An example of the use of secondhand data in Secondary Science

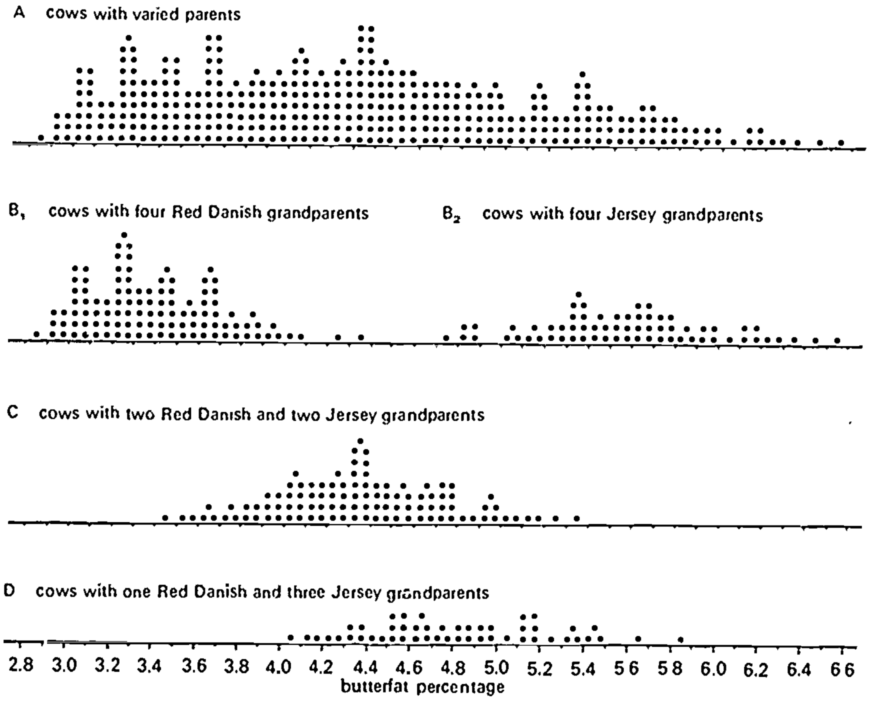
The data for the investigation "Variations in butterfat for cows of different ancestry" were taken from a scientific publication. The worksheet example contains questions based upon these graphs, illustrations of the various breeds of cattle, and on data concerning average milk yields of each breed. The portions of the suggested worksheet that are omitted from this figure contain questions based upon the results of another investigation, "The butterfat content of milk," in which students determine the fat content of commercial milk. (Reduced from George Wigglesworth, *Nuffield Secondary Science: Theme 2, Continuity of Life* (London: Longman, 1971). pp. 98-100)

III

Variations in butterfat for cows of different ancestry

Figure 53 Variations in butterfat for cows of different ancestry. Each dot represents a cow. *After Hammond, J. (1963)* Animal breeding. *Arnold*

REQUIRED
5cm × 5cm slide viewer or projector
5cm × 5cm slide or coloured picture of Jersey cow
5cm × 5cm slide or coloured picture of Red Danish cow
5cm × 5cm slides of data in figure 53



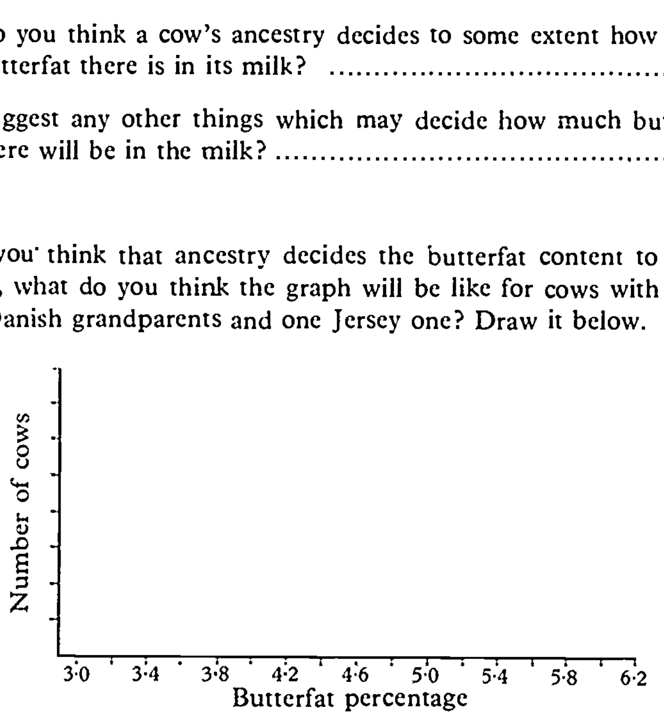
WORKSHEET EXAMPLE using graphs in figure 53

6. Look at *C* and *D*.

a. Do you think a cow's ancestry decides to some extent how much butterfat there is in its milk? ....

b. Suggest any other things which may decide how much butterfat there will be in the milk? ....

7. If you think that ancestry decides the butterfat content to some extent, what do you think the graph will be like for cows with three Red Danish grandparents and one Jersey one? Draw it below.



8. By law, milk which is sold at the extra price for Channel Island milk must have at least 4.0 per cent butterfat and [illegible]ary milk must have at least 3.0 per cent.

a. Is it important to know about the inheritance of butterfat content? Give reasons for your answer.

b. If you were a farmer owning some cows which often gave milk with a butterfat content below 3.0 per cent, what would you do?

c. Would you keep calves from these cows?

d. If you did keep them, what kind of bull would you choose as the father?

e. Would you ever use a non-Channel Island bull, like a Red Danish, with your herd? If so, why?

9. Farmers get more money for Channel Island milk. Why do they keep non-Channel Island breeds?

The figures below will help you to answer this question.

Breed of cow	*Yield of milk after calf* (about 1 year's yield)
Red Danish (in Denmark)	4600 litres
Ayrshire	4000 litres
Friesian	4500 litres
Channel Island: Guernsey	3450 litres
Jersey	3270 litres

10. Look at the photograph (or slides) of Jersey and Danish Red cows. Write down other things which might be inherited besides milk yield and butterfat content.

a. ....

b. ....

c. ....

d. ....

11. How do you think these breeds of cow were produced? What other animals can you think of which have been bred to produce particular differences?

ERIC

Course Construction

The organizers of *Secondary Science* estimate that a teacher would only cover about sixty percent of the material in a three year course allocated five forty-minute periods per week. This "over-supply" of material is deliberate, for, as pointed out previously, the materials are designed as sources for teachers designing courses for their own particular social and physical environment.

Principles of designing *Secondary Science* courses are stated and discussed in the *Teachers' Guide*. Teachers need to be certain that all content essential for *their* students is included in the course developed, or has been given in previous courses. A coherence of subject matter should be aimed at in the course selected, although "it is not always necessary to find a bridge from one piece of work to the next."[20] The overlaps and links between Fields and Themes help in planning coherent courses. Much of the material can be used, with differences in depth of treatment, at any age from 13 to 16. However, it is recommended that some ideas, such as the all-pervading concepts of energy, should be taken early in the work.

When the major areas of significance for the pupils have been determined, a balance of major and minor Themes can be planned. A major treatment of a Theme could take from one and one-half to two ten-week terms, omitting work that has been covered previously or which lacks significance for the students concerned. Minor Themes might be allocated between one-half and one term, depending on the number of Fields included. Teachers are strongly advised not to omit study of any Theme entirely, and are warned against using isolated good ideas they find in the Themes: "random selection of 'interesting' material" will not establish the major scientific principles within a meaningful pattern of "fundamental knowledge."[21]

Twelve examples of courses derived from *Secondary Science*, selected in the light of teachers' comments and experience in the trials, illustrate some of the many possible combinations and order of Themes. Two of these sample courses are appended at the end of this chapter. Although a Theme might be allotted two terms in planning, all of its Fields are unlikely to be studied in the same block of time. Appropriate sections are included where they best fit, in terms of course coherence or complexity of concepts.

Although trials have shown the validity of the suggested courses, teachers are not expected to find any one entirely suitable to their needs. They are merely examples to assist in planning.

Interdisciplinary Work

Specific suggestion of areas where teaching across traditional subject boundaries is possible are made in the *Teachers' Guide*. Areas seen as particularly suitable concern interactions of science with moral, social, economic, aesthetic, and technological issues. It is suggested that co-operative planning with the teachers responsible for social science, religious education, and English can help a broader understanding of the moral issues related to human reproduction and conservation, for example. Similarly, economic implications of geology and the aesthetic aspects of work on light and sound can provide other curricula links. Technological and craft applications can be encouraged. Interested students could design and make some science equipment in the craft shops. Additional problems suitable for a technological approach are given for each theme, including, for example:

> Theme 2—Devices for detecting the movement of a particular bee into or out of the hive.
>
> Theme 7—Test rigs for metals, fabrics, and building materials.[22]

No detailed suggested solutions to these design problems are given; they are merely illustrative examples of possible extensions.

Additional Materials

Visual Aids. The film loops produced for *Secondary Science* form integral parts of work suggested in some Fields. They serve a variety of functions; revision and consolidation of techniques *(Pouring and Streaking);* demonstration of experimental work that cannot be shown in the school laboratory *(Progeny Testing);* provision of secondhand data difficult to obtain in other ways *(Car Crash in Slow Motion);* animated visual models *(Cleaning Mechanism of the Lungs);* visual representation of abstract material *(Human Hormones);* introduction of topics *(Gliding and Soaring);* and as a method of consolidation *(Energy in Action).* A full list of titles is included in the Bibliography.

Sets of photographs and transparencies on a number of topics are also available from the publishers. These include illustrations providing sets of secondhand data for the study of human physical and cultural evolution, and the analysis of forces involved in car crashes. Land forms and weather patterns are illustrated by photographs taken from orbiting satellites.

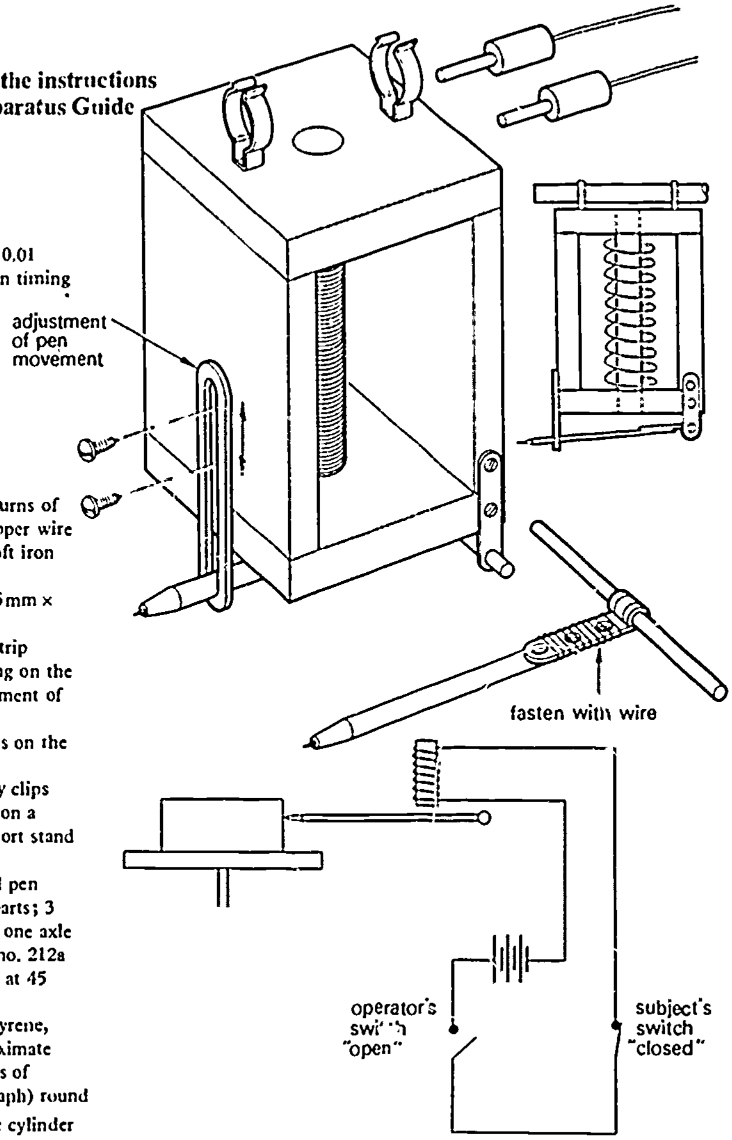
Background Readers. Some background readers, in addition to the appropriate titles developed by other Nuffield projects, are being prepared. Titles available are listed in the Bibliography.

Apparatus Guide. An apparatus guide published in conjunction with the Themes contains details of the apparatus for each suggested exercise, including the quantities needed for a class of thirty-two pupils. Detailed instructions for construction within the school are provided for some items of equipment. Figure 6.3 is an example of the type of instruction provided.

FIGURE 6.3
One example of the instructions given in the Apparatus Guide

Diagram 26
Reaction timing apparatus
Field of study 3.4

This unit may replace the 0.01 second clock in the reaction timing apparatus circuit.



Components
electromagnet: wind 400 turns of 21s.w.g., enamelled, copper wire on a 12mm × 100mm soft iron core
frame: 12mm plywood, 75mm × 75mm × 100mm
Mount a slotted metal strip 15mm wide × 40mm long on the front; this allows adjustment of the pen position
Mount two 4mm sockets on the rear
Attach two 12mm Terry clips for mounting the frame on a horizontally clamped retort stand rod
paint brush or fibre tipped pen
pen mounting: Meccano parts; 3 perforated strips no. 6a, one axle no. 15b, one connector no. 212a
gramophone turntable: set at 45 rev/min.
cylinder of wood or polystyrene, diameter 21.4cm, approximate depth 7cm. Attach strips of paper (preferably cm graph) round the circumference of the cylinder

(Photographically reduced from Keith M. Roberts, *Nuffield Secondary Science: Apparatus Guide* (London: Longman, 1971), p. 206.)

APPENDIX TO CHAPTER 6

Two of the twelve alternate pathways suggested by the developers of *Secondary Science* are reproduced in this appendix. The appendix is photographically reduced from pages 33 to 35 of the *Teachers' Guide*.

Route 3	In this route three basic ideas, energy, matter, and life are developed. It takes into account the seasonal nature of some of the material and attempts to maintain variety both in content and approach.		
Year III	Theme 2	2.11	Introductory work on life cycles (*Note:* Much of this work would go on throughout the year)
	Theme 4	4.11	An introduction to energy in action
		4.21	Experiencing and measuring forces
	Theme 3	3.11 to 3.13	inclusive. Physical activity: gaseous exchange, fuels (food)
	Theme 7	7.11	Classification
		7.31 to 7.33	Fuels (simple treatment)
	Theme 3	3.21 to 3.23	inclusive. Conception to birth, physical development during childhood
	Theme 4	4.31 to 4.33	Electrical transmission of energy (d.c. only)
	Theme 1	1.1	Environmental studies *linked with*
	Theme 2	2.12	Aspects of life cycles
	Theme 1	1.2	Some basic exchanges
Year IV	Theme 5	5.1	Human limitations—extending the range of sense perseption
		5.41	The telephone
		5.31	The camera *linked with*
	Theme 3	3.41	The eye
	Theme 5	5.32 and 5.33	Illumination and using lenses and mirrors
	Theme 4	4.34 to 4.36 inclusive	Alternating curren. motors and dynamos, converting a.c. and d.c.
	Theme 2	2.13	The importance of man's knowledge of life cycles
		2.2	Mechanism of inheritance
	Theme 8	8.4	The Earth's crust
	Theme 7	7.51 to 7.54	inclusive. Radioactivity

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Year V	Theme 4	4.12	Energy and movement
	Theme 6	6.11–6.13	inclusive. Transport
	Theme 7	7.34, 7.35	Fuels and air pollution
		7.24	Effects of environment on metals
		7.39	When will all our fuel be used up?
	Theme 4	4.41 and 4.42	Heat energy
	Theme 3	3.31 to 3.33	Health and hygiene
	One or more of the following topics:		
	a. Theme 1	1.4	Disease, pest, and weed control
	b. Theme 3	3.24 and 3.25	Adolescence, maturity, and ageing
	c. Theme 5	5.42 to 5.43	The use of transistors in radio and in switching circuits
	d. Theme 2	2.31 and 2.39	Aspects of evolution
	Theme 7	7.56	Biological effects of radiation
	e. Theme 4	4.43 and 4.44	Problems of bringing energy to bear
Route 4	Theme 5	5.1	Sense perception and extending its range
Year III	Theme 3	3.41	
	Theme 5	5.21 to 5.23	inclusive. Characteristics and transmission of sound
	Theme 3	3.12 (part of) 3.14	Blood as a transport medium. Ventilation mechanism
		3.21	Fertilization to birth
	Theme 2	2.12 (parts of)	Embryology, maturation, and parental care
	Theme 3	3.22 to 3.25	inclusive. The first six months to ageing
		3.3	Health and hygiene
	Theme 7	7.43B	Cleaning materials
	Theme 4	4.11	Energy conversion
		4.21 to 4.25	inclusive. Man's energy and his physical limitations
	Theme 3	3.11, 3.12	Experience of physical activity and gaseous exchange
	Field work from Fields 1.1 or 8.4 could be introduced during the summer term if time allows.		
Year IV	Theme 3	3.13, 3.15	Fuel, heat production, and temperature regulation
	Theme 7	7.31 to 7.34	inclusive. 7.37 Fuels
		7.5	Radioactivity
	Theme 2	2.24	Human inheritance
	Theme 6	6.22, 6.25	Movement of animals' limbs, walking, running, and jumping
		6.15	Air transport
		6.21, 6.28, 6.29	Movement for a purpose, flying, swimming
	Theme 1	1.3	Population studies

Year V

Theme 6	6.11, 6.12, 6.14	Starting and stopping	
		Land and water transport	
	6.16	Falling and going round in circles	
Theme 8	8.1	Travelling in space	
Theme 4	4.31 to 4.33 inclusive.	Versatility of electricity, simple d.c. circuits	
	3.4	Senses, behaviour, and learning	

In the last term the pupils might be given a choice of projects of which the following is an example:

Project on house or kitchen design carried out with the co-operation of home economics, craft, and social studies departments.

Theme 7	7.43, 7.44	Bleaches, disinfectants, solvents
		Emulsions, cosmetics, paints, polishes
	7.4C	Fibres and fabrics
Theme 6	6.21	Kitchen planning
Theme 7	7.4A	part of 'Modern plastics'
Theme 5	5.32'	Illumination
Theme 2	2.13	part of 'Plant propagation'

Alternatively the pupils might tackle some of the more difficult work in Secondary Science

5.42–5.43 inclusive.	Radio, the transistor as a switch
4.4	Problems of bringing energy to bear

The introductory work on the senses is selected for its significance, its organization, and the demands it makes on the pupils as well as for its content.

The pupils then study the life cycle and enough physiology to understand it. This work leads naturally to investigations on hygiene, bacteria, and detergents. Sufficient time must be left in this year to give the pupils full experience in the work on energy conversion and man's energy.

In the fourth year the work on fuels is introduced through an initial study of foods. Radioactivity is introduced here for its emphasis on its uses and for its questions about genetics.

Selected parts of Theme 6 carry on from some of the work on man.

In the last year at school we are concerned with the adult world including man's need to understand himself.

7

THE SCHOOLS COUNCIL INTEGRATED SCIENCE PROJECT

The publication by the Nuffield Foundation of *Combined Science* and *Secondary Science* materials has assisted teachers to plan *science* courses (instead of *biology*. or *chemistry*, or *physics)* suitable for all children in secondary schools during the years of compulsory education, except for students in the last three years (grades 9-11) of courses leading to GCE O level science examinations. This gap will be filled by 1973, when materials from the Schools Council Integrated Science Project (SCISP) will begin to be available commercially. SCISP is one of a number of projects, sponsored by the Schools Council,[1] which is developing curriculum materials for use in the schools of England and Wales.

SCISP is currently (1972) in its second trial year, and the materials finally produced may differ from those described in this chapter. However, the assumptions upon which the course is based, the broad outline of the material to be included, and the general form of the publications is unlikely to differ substantially from the present intentions.

Although SCISP is intended to be a course mainly for students (of above average ability) it is not entirely restricted to this group, at least in the third year in secondary school. There is an increasing number of secondary schools, mainly "comprehensives," that do not wish to commit students at the end of their second year to a decision on which, if any, of the examinations they will ultimately attempt Since no rigidly prescribed order is planned for SCISP. teachers should be able to devise a course suitable for all ability ranges by choosing appropriate components from SCISP and the highly flexible *Secondary Science*. This will almost certainly be possible for the third year, preparing students for study of either SCISP or *Secondary Science* in years four and five.

However, SCISP is *primarily* intended for students studying science in preparation for a GCE examination leading to a "double O level" pass (i.e. an examination equivalent to two normal subjects). It is expected that SCISP students will spend six or seven periods per thirty-five period week studying science in each of their third, fourth and fifth years of secondary schooling.

It has been assumed that students using SCISP will have had a science course such as *Combined Science* or *Science 5/13* before they enter their third secondary year. In this previous course it is assumed that students will have gained the following skills and knowledge:

Skills:

- Handling of basic heating equipment;
- Handling of test tubes, beakers, flasks;
- Handling of supporting equipment (retort stand, boss, clamp):
- Using measuring instruments (ruler, balance, measuring cylinder, pressure measuring instruments, thermometer);
- Filtration, distillation;
- Basic circuits, including use of meters.

Knowledge:

Science

- Acidity, neutralization; acid, alkali, salt;
- Element, mixture, compound, metal, nonmetal;
- Solid, liquid, gas; change of state, solution;
- Reproduction: asexual and sexual patterns in plants and animals;
  human reproduction;
  elementary ideas of development and growth;
- Cells: simple ideas of structure
- Microorganisms: culture, types, control
- Forces
- Qualitative ideas of volt
  amp
  resistance
  velocity
- Experience of energy transformations
- Simple interactions, e.g. of oxygen and other elements
- Simple activity series

Mathematics

- Scales, magnification (e.g. maps)
- Basic computation
- Graphs and their interpretation: histogram, straight line, and nonlinear
- Percentages
- Volume and area.

In addition, it is hoped that beginning students will be able to use force measuring instruments; be familiar with pH scale; be able to use logarithmic scales and index notation for large and small numbers; and be familiar with geometric progressions, proportionality, and the computation of area of circles and volumes of spheres.

Aims

Only a minority of the students using SCISP courses are potential professional scientists. Therefore, for most of these students, science is a general education course, "primarily concerned with inculcating attitudes such as 'critical thinking' or 'objective observation' . . . [But they must also obtain] enough knowledge to enable them to have some appreciation of the influence science has on their lives and to be able to comment on scientific issues in an informed manner."[2] The skill objectives emphasized in SCISP are mainly intellectual ones, rather than those of manipulative technical dexterity.

The tentative broad aims of the course, which guide the formation of operationally defined behavioral objectives for each stage of the work, are listed in Table 7.1, p. 81. These aims have been revised as the result of data obtained during formative assessment, and differ from the list in the Draft Working Paper. The list in Table 7.1 is not definitive; further changes may occur before final publication.

Comments in the Draft Working Paper help to clarify the intent of these general aims. For example, the following statement concerning aim 1.A indicates the *type* of knowledge thought necessary for these students;

> It is more useful for the future A-level chemist to know that $2H_2$ represents two molecules of hydrogen than it is for him to know that the formula of hypo is $Na_2S_2O_3.5H_2O$. It is more useful for the future technician to know that acids can be stored in polythene than it is to know details of the lead chamber process. It is more useful for the future citizen to know that it is safe to touch his car battery terminals but dangerous to touch the mains electricity supply than it is for him to know the Wheatstone's bridge circuit. And it is more useful for all pupils to know some facts about reproduction than it is to know how to dissect a dogfish.[3]

This excerpt from the Draft Working Paper also indicates the emphases on providing material which is of some potential value to the students, and on general principles rather than very specific facts; on what the *Secondary Science* team calls "significance" for the pupil. Similar values are reflected in the rationale for the choice of "attitude" aims: "pupils should be aware that some decisions must be taken in life before all the relevant evidence can be gathered;"[4] "scientific discovery affects human beings: science may be amoral, but scientists need not be!"[5] The "skill" aims are also clear reflections of this general position of "relevance" or "significance."

Patterns

To guide the development of materials for an integrated science course two existing models of science curricula were combined to produce what the organizers call the "Patterns Approach." This approach combines the feature of the "process approach," which considers the "processes of

TABLE 7.1

Aims of the Schools Council Integrated Science Project

(From William C. Hall. "Case study in curriculum decision making: the Schools Council Integrated Science Project," *Australian Science Teachers Journal* 17(3):19-27. October, 1971. p. 20.)

Knowledge

1.A. To recall and to understand that information which would enable pupils to take A-level courses in biology, physics, chemistry, or physical science, would enable them to follow a job in science and technology, would enable them to read popular scientific reporting and would enable them to pursue science as a hobby.

2.A. To understand the importance of patterns to the scientist and to use these patterns in solving problems (both of a laboratory and of a household type).

3.A. To be able to recognize scientific problems.

4.A. To understand the relationship of science to technical, social and economic development, and to be appreciative of the limitations of science.

Attitudes

1.B. To be faithful in reporting scientific work.

2.B. To be concerned for the application of scientific knowledge within the community.

3.B. To have an interest in science and technology and be willing to pursue this interest.

4.B. To be willing to make some decisions on the balance of probability.

5.B. To be willing to search for patterns, to test for patterns, and to use the patterns in problem solving.

6.B. To be sceptical about suggested patterns.

Skills

1.C. To work independently and to work as a part of a group.

2.C. To discover and to use available resources such as books, apparatus and materials

3.C. To organize and to formulate ideas in order to communicate to others and as an aid to understanding critical analysis, etc.

science" (what scientists are thought to do) of most importance, and the "conceptual approach," which aims to develop an awareness and understanding of some major scientific concepts. The search for "Patterns" among the concepts developed by applying the scientific processes[6] provides the major integrating theme, indicating that the activities of science are similar in all of the historically distinct branches of the subject. Integration is not being achieved by forcing content into a unified mould, but artificial separations are not being perpetuated. The fundamental concepts of science upon which the whole of the content is based are the notions of *building blocks, interactions,* and *energy.*

When studying the *building blocks* (electrons, ions, atoms, molecules, cells, organisms, populations, communities, and planets) the emphasis is on their nature, properties, complexity, and size. Where necessary, and useful for understanding, the available evidence for their existence and connections is examined.

Interactions is concerned with the effects of interactions between building blocks, or building blocks and energy. For example, students will be concerned with the interactions of molecules to form new molecules; the interactions of organisms within populations and food chains; and the interactions of electrons with electrical fields.

In the *energy* content theme the intention is to show that energy, which can have different interconvertible forms, is directly comparable in terms of form and change whether it is in living or physical systems. It is shown that in energy conversions useful work can be done, and that the "final" form of energy is heat. The sociological implications of energy transformations and use are stressed.

The project model is summarized as a tetrahedron, with the three major concepts forming the base, while the unifying apex indicates the search for patterns to be used in problem solving (Fig. 7.1, p. 83).

The following major patterns are listed in the Draft Working Paper: Chemical—Periodic Table; Chemical—Electrochemical series; Chemical—Rock Cycle; The Atom; Structure of Substances; Energy; Motion; Structure and Function; Society; Environment; Genetic Continuity; Evolution. Table 7.2, p. 83, reproduces part of a summary chart from the working paper indicating the "important ideas" within each major pattern. The excerpt illustrates two points: the use of theoretical explanation and the relationship of science to other aspects of human society.

Students do ·· the idea of patterns, although the patterns that they identify are not always the major patterns the course developers have listed. For example, the following conversations took place with two separate groups of students at a selective, private girls school. The first group

FIGURE 7.1

Model used by the Schools Council Integrated Science Project to summarize the relationships between content and the integration achieved by searching for patterns

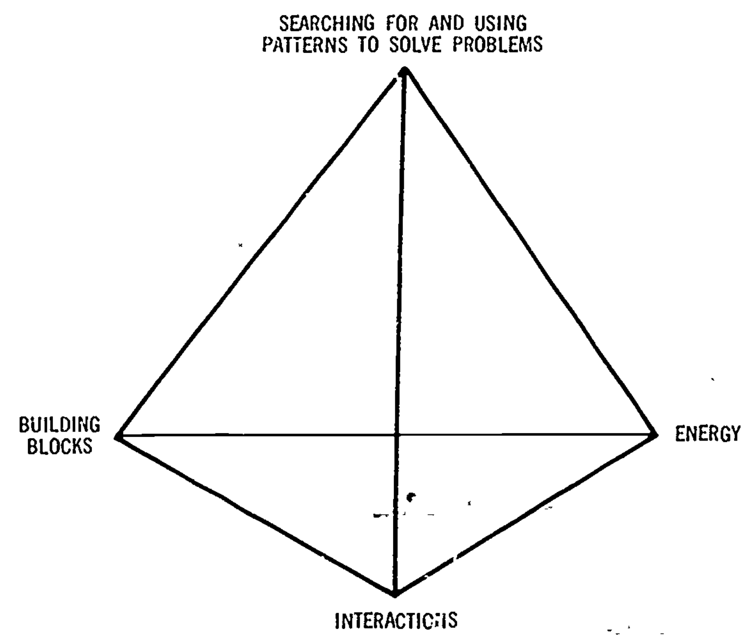


TABLE 7.2

Excerpt from a chart listing the important ideas associated with the major patterns that form the basis for the development of SCISP

(Based upon: Schools Council Integrated Science Project, *Draft Working Paper,* p. 5-23.)

MAJOR PATTERNS	IMPORTANT IDEAS
The Atom	(a) The atom can be regarded as a series of models (b) The models may be used to explain observable physical and chemical phenomena
Structure of Substances	(a) Solids are assumed to be giant ionic, giant covalent or metallic (b) Liquids and gases are assumed to be covalent molecules (c) Interactions between molecules contribute to overall pattern
Energy	(a) Interconversion and conservation of energy are important principles (b) Man's use of energy is important to the economics and well-being of a community

identified a pattern that is among the intended major patterns, but the second group's example, "limiting factors," is not listed. (The lesson was concerned with energy transformations in cells.)

Group 1:

"What are some of the things you like about the SCISP Course?"

"And we have to work out patterns and so on in this course, which is quite fun."

"So you do look for patterns. Are they physics patterns and chemistry patterns, or do some patterns work in physics, chemistry and biology?"

"Yes, they do."

"Such as?"

"Well these patterns with cells, for instance. You have the energy, and what releases the energy and so on and that . . ."

"Yes, chemical potential energy produces molecular energy and . . ."

"Yes, and that same pattern came up in physics, for instance."

Group 2:

"What sort of patterns do you use? Can you give me an example of one?"

"In the way some substances don't interact anymore after a certain level, and in the reproduction of some animals. There's a limiting factor . . ."

"In the number of individuals in the community . . ."

"If it uses above a certain level of numbers, it sort of gets to a limit."

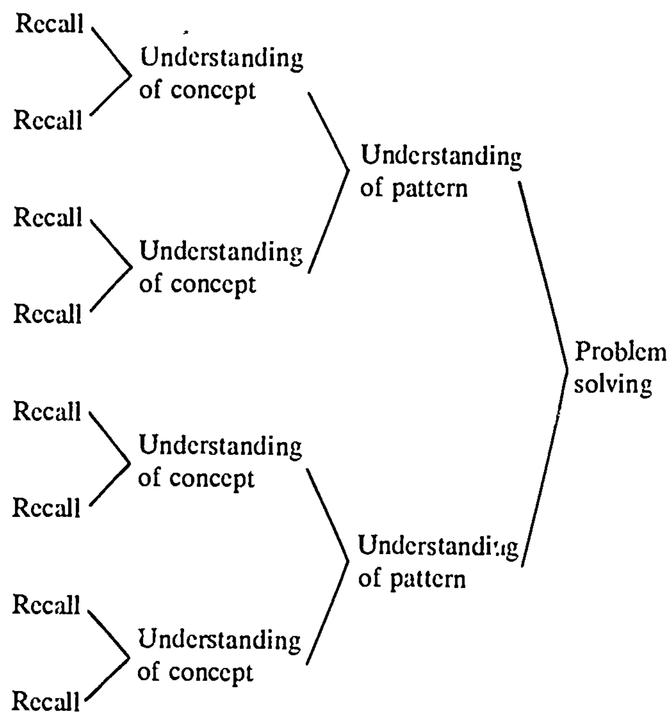
"So you think you can see this pattern of limiting factors in all sorts of places?"

"Yes. Sometimes plants as well."

"Yes, and you can help chemical interactions by adding heat; but soon it won't do any more."

Instructional Model

The sequence of development is firmly based on a modification of Gagn'an learning heirarchies. The materials are planned so that students will learn, and be able to recall, basic knowledge before being expected to learn and understand concepts. A number of concepts, when understood, can be combined to form a pattern. Patterns can then be used to solve problems. These four levels of learning—recall, concepts, patterns, and problem solving—are claimed to correspond approximately to Gagné's multiple discrimination, concept learning, principle learning, and problem solving. The SCISP team visualize the relationships of these levels as follows:[7]



At the beginning of each section of work the trial *Teachers' Guides* illustrate the relationship in a "flow chart" showing which portions of work provide the appropriate information to be recalled, how these contribute to a concept, and how the resulting patterns can be used to solve particular problems. Figure 7.2, p. 86, illustrates the flow chart for Section 17: Earth, water and organism interactions.

The acceptance of this heirarchical model, coupled with a teaching technique which, in general, uses a "guided discovery" approach, is a reflection of the attitude of the course organizers. They believe that

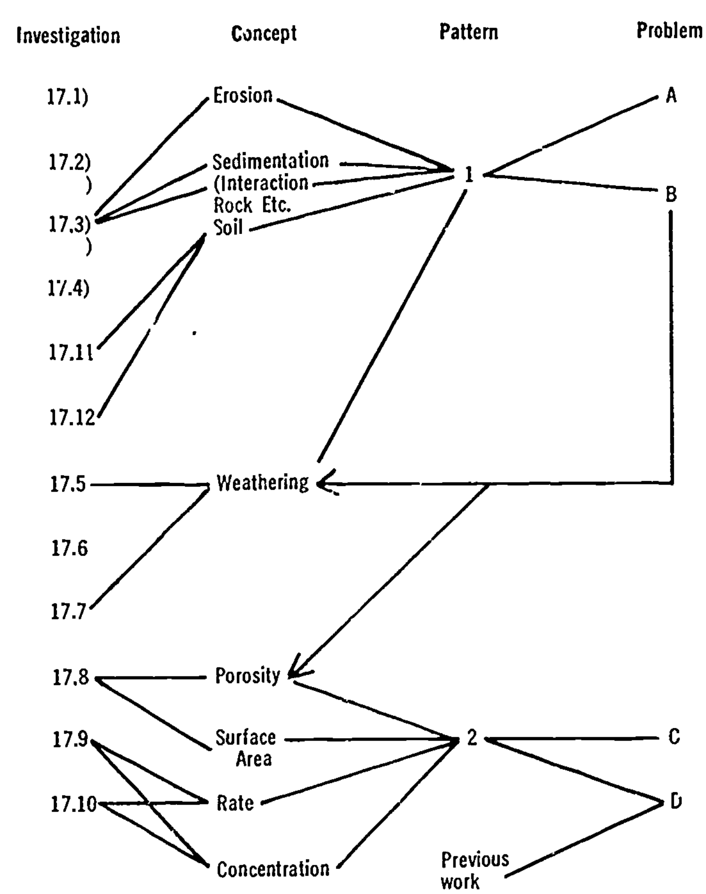
> on the one hand knowledge of a 'stamp collecting' type is not useful, but that knowledge should be used to solve problems; on the other hand we believe that to face the pupil with a problem without the necessary background information is probably a waste of time and can be frightening.[8]

FIGURE 7.2

Flow chart for section 17 of the trial version of the Schools Council Integrated Science Project sample scheme

The investigation number, and the problem identification (letters A-D), refer to sections of the pupils' manual. The investigations are titled, respectively: A Field Trip; The Lynmouth Flood; River action; Investigating river action in the laboratory; Homes and their environment; Insuring against disaster; Weathering of buildings; Porosity; Solid size and rate of reaction; A further look at concentration and rate of reaction; What is soil?; and Interactions between man and the soil. Patterns 1 and 2 are stated in the objectives for the section and concern the rock cycle and factors affecting rate of chemical reactions. These are subsidiary patterns, not the major patterns identified in the text.

(Redrawn from Schools Council Integrated Science Project, *Patterns: Teachers Guide 6,* Trials version, p. 17-2.)



Content

A cryptic summary of the content of SCISP is provided at the end of this chapter where the provisional Sample Scheme outlined in the Draft Working Paper is reproduced. The Sample Scheme is seen as only one of the many possible sequences of instruction compatible with the aims and objectives of SCISP. It is, however, the course for which the materials are being prepared. The teachers' guides, pupils' manuals, background books, and technicians' manuals are being prepared for publication specifically to meet the sequence requirements of this particular course.

The emphasis on social and technological implications that permeates the course is not readily apparent from the topic listing on the Sample Scheme. Some of the methods of introducing these aspects can be seen in the following excerpts from a trial version *Teachers' Guide*. The first is from the introduction to the section *Communities and Populations:*

> Patterns of community structure, development and interaction are rather diffuse but knowledge of them is essential if man, in his wisdom, is not to interfere (often to his own cost) with their structure and with the mechanisms controlling their stability. The overgrazing question is one way in which this might happen. This initial look at community patterns confines itself to size, composition and distribution, and with colonization. Communities are composed of populations the interactions of which will become clearer as the course progresses. In the section on competition the way in which populations interact during colonization is further investigated by taking up the threads from this section. Knowledge of the size of the human population is essential to planners and some ways in which this may be estimated are examined. The work includes a look at sampling processes and their reliability. Colonization involves the growth of a population, and the patterns of population growth and change and the factors which affect them are currently of considerable human concern. A final problem on the future population of coloured immigrants in the U.K. is an attempt to place discussion in a rational and objective seeting.[9]

In the following extract reproducing the objectives for section 17, *Earth, Water and Organism Interaction,* the numbers in parentheses refer to the major aims of the course listed in Table 7.1.

Cognitive Objectives

1. To understand that the earth's surface is involved in interactions which result in cycles of weathering (soil formation), erosion, transport of sediment and sedimentation which are summarized in 'the rock cycle'. (2A)
2. To understand that reaction rate can be effected by surface area and concentration of reactant(s). (2A)
3. To know that erosion can be a costly nuisance. (4A)
4. To know that soil formation also involves an interaction with organisms. (1A)
5. To understand that man, organisms and the surface of the earth interact with considerable agricultural, industrial and sociological implications. (4A)

6. To be able to recognize a problem arising out of a partially completed rock cycle. (3A)

Non-Cognitive Objectives

1. To develop an interest in the interaction between man and the earth's crust which will enrich everyday life. (3B)
2. To be able to use given resources to solve the problem mentioned in Cognitive Objective 4. (2C)
3. To work together in discussing data and the results of investigations. (1C) [10]

Materials

Pupils' Manuals. Trial *Pupils' Manuals* contain instructions for investigations, some background material, and statemen of problems. The investigations are usually. but not exclusively, concerned with laboratory or field observations; occasionally some second-hand data is provided. Some of the "problems" utilize second-hand data; others are questions requiring explanation of phenomena in terms of previously established patterns; many include experimental design and execution as part of the solution.

The *Pupils' Manuals* also contain some discussion questions, often based on excerpts from the press, and occasional cartoons which can serve as a basis for discussing various topics (Fig. 7.3, p. 89).

In the final published version there will be three *Pupils' Manual.*, provisionally entitlea *Building Blocks, Energy*, and *Interactions*. Background books are being written to provide information on specific topics. These books, together with those written for other Nuffield courses, are to be used in conjunction with the *Pupils' Manuals* and provide additional data to help establish patterns.

Teachers' Guides. In addition to an outline of the objectives of each section, a flow chart (Fig. 7.2), and teaching notes on suggested demonstrations and investigations, sample questions to test each of the specified objectives of the section are provided. Teachers are sometimes given anticipated results of exp ments devised for this course, and when experiments from the original Nuffield courses are used, are referred to the appropriate teachers' guide. (A deliberate effort has been made to incorporate resources already within the schools: Financial commitments on new equipment and the amount of time teachers have spent familiarizing themselves with the new materials have been considered.)

Suggested times for each activity, background data and information for use in discussion, possible alternative methods for establishing concepts, and notes on the culturing of organisms or operation of equipment are provided.

FIGURE 7.3

Sample page from a trial version pupils' manual of the Schools Council Integrated Science Project illustrating the use of cartoons to provoke discussion

(Photographically reduced from Schools Council Integrated Science Project. *Patterns: Pupils' Manual 5*, Trial version. p. 47.) (Cartoon copyright: reproduced from the *Daily Mirror* by permission of Syndication International.)

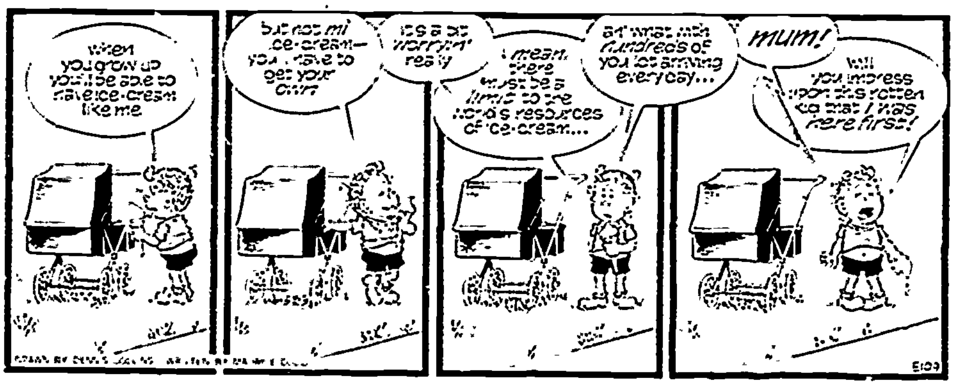
PART 3 : CHANGE

In Part I of 'Patterns' you were investigating the nature of different building blocks, how they were connected, and attempting to discover their sizes. What does the scientist mean when he talks about the 'size of a molecule'? What does the scientist mean when he talks about the 'size of a population'?

In Part II you were looking at some of the different forms of energy, seeing how energy can be transformed and how work can be done. In both Parts I and II, the word 'interaction' was used. What do we mean by the term 'interaction'? In Part III of 'Patterns', which is called CHANGE, you will be using the word 'interactions' again.

15 distribution of building blocks

In this section we shall be answering the questions 'How are building blocks distributed?', and 'What are some of the effects that building blocks have upon each other?' First there will be a general look at your locality, followed by your country; next the world, and finally our solar system. A more detailed look at the distribution of one or two building blocks will complete the section.



Investigation 15.1 Building blocks in the locality

Carry out a general survey of your locality. Try to answer the following questions:

(a) Comment on the variety and types of living building blocks in your area.
(b) How were the rocks in your locality formed?
(c) What is the nature of, and the differences between, the atomic, ionic, molecular or giant structure building blocks?
(d) Are the living and non-living building blocks evenly or unevenly distributed?

Discussion in class will indicate how to look for answers to these questions.

Technicians' Manuals. Each student investigation, problem, teacher demonstration, or discussion is listed in the *Technicians' Manuals.* For each, the amount and nature of the necessary apparatus, chemicals, teaching aids, and reference materials is listed. Notes on the construction and operation of apparatus, and the preparation of reagents are provided. Teachers in the trial schools report that these guides make it a much simpler matter to prepare for classes; technicians need only be told the number of the exercise, and they can quickly prepare the materials required. Even for schools without technicians, the convenience of a compact listing of requirements makes planning simpler.

Publication

Publication, under the general title "Patterns," of the *Pupils' Manuals, Teachers' Guides, Technicians' Manuals,* and background readers is planned to begin in Spring, 1973 and be completed by Summer, 1974. A short book outlining the scheme and the approaches to teaching and assessment is also planned. All materials will be published by the Longman Group.

APPENDIX TO CHAPTER 7

THE SAMPLE SCHEME

It is emphasized that this is only one possible sequence of material which is based on [the general aims of the course].

YEAR 1

Introduction.

The three useful ideas (building blocks, energy and interactions) outlined. The importance of the 'searching for and using patterns' as a unifying thread throughout.

Part I

This part is concerned with establishing some of the important building blocks. One of the themes will be the graduation in size and the difference in nature of the building blocks. This is followed by a brief look at some interactions.

Section 1: The Earth and Life
Atmosphere, water, land, and life. The diversity of living things past and present. Nomenclature. Rocks and minerals; man's use of these. Some geological patterns.

Section 2: Crystals and Atoms
External and internal patterns. Natural crystals. Making crystals. External pattern an indication of internal pattern. Crystals of elements. Allotropy. Giant structures. Electron micrographs. Atoms: early ideas, g atom and atomic weight. Spectroscopic evidence.

Section 3: Molecules
Physical evidence. Size. Simple idea of chemical bond. Formulas and g formulas. Patterns of combination. Avogadro's number. Boyle's and Charles' Law. Kinetic theory (first look). Patterns of matter behaviour.

Section 4: Cells
Giant molecules (first look). Cells. Pattern to the structure of living things. Use of electron microscopy.

Section 5: Reproduction, growth and development of organisms
Forms of reproduction. Sexual forms involve the union of cells. Patterns of development and growth. The concept of the life cycle.

Section 6: The organisms and water
Water loss and gain. Osmosis. Adaptation (treated in terms of water relationships of organisms). Adaptability.

Section 7: Populations
Collections of similar individuals. Population growth. Factors affecting population size.

Section 8: Variation, adaptation and selection
Continuous and discontinuous variation. Darwinian ideas of natural selection. Gaps in Darwin's argument.

Section 9: Atomic and molecular interactions
Chemical reactions. Equations. Patterns of reaction. Energy changes. An energy pattern. Energy not the only consideration.

Part II

Here we are concerned with different kinds of energy and their transference. Sociological implications and technological applications will be stressed.

Section 10: Doing Work; Kinetic and Potential Energies; Energy and Life

Kinds of energy: revision. Energy changes and energy patterns. Machines. The 'muscle-bone' machine. Power. Respiration. Food and fuels. Earth's energy sources. Mechanisms of breathing, digestion, transport, elimination of waste and homeostasis.

YEAR 2

Section 11: Wave Energy

Light. Photosynthesis. Wave patterns. Properties of light. Solar radiation. Electromagnetic spectrum. Optics. The eye. Photography. Spectroscopy.

Section 12: Sound

Another form of wave energy. Wave patterns. Uses. Noise.

Section 13: Sense perception, linking systems, and behaviour

Limitations of sense perception. Behaviour from taxes through to complex human social behaviour. Tropisms. Linking systems. Substances influencing behaviour.

Section 14: Electrical Energy

D.C. Electromagnetism. Energy and power. A.C. S.H.M. Electrolysis. Patterns of electrolysis.

Section 15: Heat; Conservation of Energy

Energy patterns. Conservation. Heat the final form.

Section 16: Ions and the Electron

Evidence for the existence of ions. Acidity. Giant structures. A chemical pattern: electrochemical series.

Part III

Here we are concerned with various interactions and their differences (e.g. interactions of molecules are not the same as interactions of organisms).

Section 17: Distribution and dispersal of organisms

The uneven distribution of organisms. Factors influencing distribution. Dispersal.

Section 18: Atmosphere, land, and water

Atmospheric heating and movements. The water cycle. Movements of water in oceans. Weather patterns. Weathering and the land: erosion, soil formation. Sedimentation today.

Section 19: Communities and ecosystems: exchange of energy and materials in living systems

Interacting populations form communities. The nature of the ecosystem. Cycles of matter and flow of energy in ecosystems. Succession. Communities in the past. Palaeoecology.

Section 20: Competition and cooperation: inter-and intra-specific interactions of organisms

Patterns of interaction between organisms: competition, parasitism, social groups. Social groupings of man.

YEAR 3

Section 21: Newton 1, 2 and 3; Planetary interactions
Patterns of motion; space. The solar system. Earth motions.

Section 22: The earth and its history; interactions of atmosphere, land and water
Earth's gravitational field. Earth's magnetic field. Atmosphere, land and water. The earth's crust and interior. The rock cycle. Earth history. Cyclical patterns of earth activity.

Section 23: Interactions of molecules
More detailed kinetic history. Reaction rates.

Section 24: Interactions of electrons

Section 25: Interactions of atoms
Chemical bonds. Another chemical pattern: periodic table. Shapes of molecules. Molecular patterns. D.N.A. Making molecules and giant structures.

Section 26: Genetic continuity
Mendelian inheritance. Gene theory. The chromosome theory. Linkage. Origin of new variation. The uses of a knowledge of inheritance. Gene action: genes in populations.

Section 27: Evolution
Extension of Darwinian theory in the light of modern knowledge. The origin of species. Human evolution.

Section 28: Modern atomic science
The atomic pattern. Radioactivity; moral questions raised.

Section 29: Environment
Landscape as the interaction of physical and living components. Man's enormous influence on the environment and his responsibility for it.

ERIC

8

SUMMARY OF OTHER BRITISH SCIENCE CURRICULUM PROJECTS

In this section short summary descriptions of the other modern science curriculum projects are provided. The publications of each of these programs are listed in the Bibliography in the order in which the projects are described.

The Nuffield O level science schemes were the first of the curriculum development projects in science to be sponsored by the Nuffield Foundation in the early 1960s. They represent schemes of work in the separate sciences—biology, chemistry and physics—for the secondary school student, grades 7-11, following a science course of five years duration and leading to the General Certificate of Education at the Ordinary level (GCE O level). This type of course and examination is taken by the top 25-30 percent of the ability range.

The basic aim of these schemes was to foster a different attitude to science subjects in both student and teacher—one of curiosity and inquiry rather than an emphasis on the uncritical assimilation of facts and the "verification" of scientific laws by routine experiments. The schemes in all three subjects are based to a very large extent on work in the laboratory with investigational problems of the open-ended variety playing a most important part. This type of approach, which can be best described as 'guided discovery', rather than pure heurism, calls for a diversity of teaching techniques, and is therefore challenging to teacher and student.

Nuffield O Level Biology

This scheme is divided into five sections, each of one year's duration. The first two years (grades 7, 8) represent an introductory phase in which the groundwork is laid for the next three years.

For the introductory phase it is expected that there will be two teaching periods per week (a period is usually 40 or 45 minutes in duration). The sequence of topics is flexible, the only governing factors being certain seasonal requirements.

The next three years represent the actual O level course in the sense that it is this portion which will be examined in the special papers available for the CCE O level. For this stage a time allocation of three periods per week (preferably one double and one single) is suggested.

The structure of the course is as follows:

Year I Introducing living things

The variety of life; investigating living things; naming living things; Cells as units of life; how living things began; reproduction and development in animals and man; living things multiply; finding out about locusts; finding out about other insects.

Year II Life and living processes

Man and microbes; the discovery of small organisms; growing bacteria; bacteria and health; man against disease; shapes, sizes and movement; size and surface in living things; movement in animals and plants; how plants reproduce and make seeds; growing up; man and his environment.

Year III The maintenance of life

Breathing; an exchange of gases; how breathing takes place; respiration; how is energy obtained?; food and life; how animals feed; problems of digestion; plants and the atmosphere; plants and light energy; the organism and water; the uneven distribution of organisms; reaching the habitat—organisms which are moved; reaching the habitat—organisms which move.

Year IV Living things in action

Becoming established in a habitat; community and succession; a community in the soil; cells and water; the control of water content; substances in solution; transport systems in animals; mass-flow systems in plants; organisms behave; structures which do things; detecting changes in the environment; linking systems; adjustment; an important 'adjustment' organ: the kidney; behaviour and survival; climax and feeding; how some living organisms provide habitats for others; how man may affect his surroundings.

Year V The perpetuation of life

Similarities and differences in living things; how do similarities and differences come about?; the material of inheritance; the origin of characteristics; how do genes work?; development; patterns of development; problems of development; different ways of breeding; genes in populations; the selection of a new generation; evolution.

For each year there is a Students Text and a Teachers' Guide. In addition there are a number of 8 mm film loops, a set of 8 slides on locust development and a set of 12 slides on pleurococcus, a record of the mating call of the African clawed toad and sets of photographs of mitosis and meiosis.

Nuffield O Level Chemistry

This scheme is divided into three stages. In Stage I, which occupies the first two years, the students are encouraged to use their hands and to learn as much as possible by doing experiments for themselves. This Stage is called *Exploration of Materials* and there are two alternative approaches suggested.

In Stage II the students are introduced at as early a stage as possible to some of the central concerns of modern chemistry—among them particle theory, molecular structure, electrochemistry, energy changes, rates of reaction, equilibria and patterns of chemical behavious. In Stage III, which occupies the fifth year, students are encouraged to study some aspect of technological chemistry; there are several options available.

Nuffield chemistry is designed as a course both for students who will not go on to study chemistry at *A* level and University and to meet the needs of those who will eventually major in chemistry. Chemistry at this level is regarded as an exceptionally valuable part of a child's general education. The recommended time allocated is similar to Nuffield biology.

The structure of the scheme is as follows:—

Stage I The Exploration of Materials

Alternative A	*Alternative B*
Getting pure substances from the world around us	Separating pure substances from common materials
The effects of heating substances	Acidity and its cure
Finding out more about the air	Fractional distillation as a way of separating mixtures
The problem of burning	The major gases of the air
The elements	Finding out more about substances by heating them
Competition among the elements	Using electricity to decompose substances
Water as a product of burning	The elements
The effect of electricity on substances	Further reactions between elements

Chemicals from the rocks
Chemicals from the sea

Investigating come common processes involving the air: a) burning and breathing; b) rusting.
Competition among the elements

Stage II The Ideas that Chemists Use

Atoms in chemistry; investigation of salt and 'salt gas'; looking at the elements in the light of the Periodic Table; Finding out how atoms are arranged in elements; solids, liquids and gases; explaining the behaviour of electrolytes; finding the relative number of particles involved in reactions; how fast?, rates and catalysts; how far?, the ideas of dynamic equilibrium; investigating the substances called 'acids'; breaking down and building up large molecules; chemistry and the world food problem; chemicals and energy; radiochemistry.

Stage III A Course of Options

Water; crystals and their orderliness; colloids; metals and alloys; chemical changes and the production of electrical energy; an investigation of the structure of a few compounds; giant molecules; the chemical industry; historical topics; acidity and alkalinity; analysis with a purpose; "atoms into ions"; periodicity and atomic structure.

For the teacher there are sample schemes for the Stages I, II and III as well as a *Handbook for Teachers* and an *Introduction and Guide.* For the student there are no course books but instead sheets of *Laboratory Investigations* for the practical work and many background readers designed to relate chemistry to the world around and to show chemistry as part of the industrial, economic and social life of the community. There is also a *Book of Data* giving fundamental constants, atomic properties, energy changes, electrical properties and similar phenomena for most elements and a range of compounds. There is in addition a number of 8 mm film loops, a pack of diffraction grids and periodic table leaflets.

Although Nuffield chemistry can be taught with the usual chemical equipment, a small number of new items is recommended. These are largely intended to reduce the time needed to perform routine operations, such as weighing and filtering. In addition the use of gas syringes is recommended for quick experiments with gases.

Nuffield O Level Physics

The emphasis in this scheme, as with all the Nuffield projects, is on pupils conducting experiments themselves. This entailed the design and production of large quantities of relatively inexpensive apparatus. In physics this has led to the development of some 40 "kits," designed to meet the needs of 32 students in a class. This is considered the maximum for a Nuffield approach. Some kits, for example the microbalance kit, include enough apparatus for students to work individually. The electromagnetic kit contains apparatus for 16 pairs of students. It is, of course, possible for teachers to make up their own kits or to economize further by expecting students to work in large groups.

At the more sophisticated level the teachers who developed the project continued the work of the Association for Science Education panels by designing certain basic equipment suitable for general purposes in a school laboratory: power supplies, amplifiers, scalers with timing facilities, oscilloscopes, meters, etc.

The structure of the course is as follows:—

Year I

Materials and molecules; making a microbalance; rough measurement; looking for a law of levers; investigation of springs; air pressure and molecules; measurement of a molecule; energy.

Year II

Forces; electric circuits; electric currents; more forces; energy; heat; heat transfer.

Year III

Waves; optics; motion and force; molecules in motion; electromagnetism; cells and voltage; electrostatics; a fruitful theory, [Teaching] the use of a theory.

Year IV

Physical basis of Newtonian mechanics; kinetic theory of gases; universal conservation of energy; power; electricity; electrons.

Year V

Motion in an orbit; electrons in orbits; the grand theory; oscillations and waves; interference of light waves; radioactivity; waves and particles.

For each of the five years of the course there is for the teacher a *Teachers' Guide* and a *Guide to Experiments*. For the students there is a *Questions Book* for each year containing a collection of test questions designed as a part of the teaching scheme. The questions test the understanding of what has been learned.

The Nuffield A level science project began in 1966 after the publication of the O level schemes. The project aimed to produce new schemes for the two-year post-O level stage (Grades 12, 13) in the separate sciences and also in physical science. Trials in a large number of schools took place between 1966 and 1968.

Nuffield A Level Biological Science

This part of the project aims to develop in students the intellectual and practical abilities which are fundamental to the understanding of biological science, to introduce students to a body of biological knowledge relevant to modern society and to develop in students the facility for independent study.

The subject matter includes four units, each of approximately 90 periods (of 40 minutes) of class work and parallel homework. The units can be taken in various sequences and there are opportunities for a flexible treatment within each unit. The outlines of the units are as follows:

Maintenance of the organism

Interaction and exchange between organisms and their environment; gas exchange systems; transport inside organisms; transport media; digestion and absorption; enzymes and organisms; photosynthesis; metabolism and the environment.

Organisms and populations

Variation in a community; inheritance and the origin of variation; the cell nucleus and inheritance; population genetics and selection; population dynamics; organisms and their physical environment; the community as an ecosystem; evolution and the origin of species.

The developing organism

Sexual reproduction; early development; cell development and differentiation; the nature of genetic material; gene action; development and the internal environment; development and the external environment.

Control and co-ordination in organisms

The organism and water; the cell and water; control by the organism; stimuli and their influences; nerves and movement; structure and function in the nervous system; social behaviour.

These units cover all levels of biological organization, i.e., molecular, cellular, organ and tissue, organism, and population. However, the focus of each is on the whole organism. They also illustrate many of the major themes or concepts of biology such as variety and adaptation, structure in relation to function, organisms in relation to their environment, the similarity of many processes of physiology and behavior in different species, the genetic and evolutionary continuity of life, matter and energy cycles, homeostasis, and the development and uniqueness of the individual.

The materials available include *Laboratory Guides* for each of the main units, together with *Teachers' Guides* to these books, a number of topic reviews, and some 8 mm film loops.

Nuffield A Level Chemistry

The treatment of chemistry at the Advanced level is based on the establishment and use of three fundamental aspects of chemistry, applied to both organic and inorganic systems:

a) The use of the Periodic Table as a means of providing a unifying pattern,
b) The relationship between structure—both atomic and molecular—and the properties of substances, and
c) The way in which energy transfers can determine the feasibility and outcome of reactions.

In presenting these fundamental aspects an attempt has been made to integrate the course in several ways:

a) By bridging the traditional boundaries of inorganic, organic, and physical chemistry
b) By linking facts and concepts,
c) By bringing theory and practical together, i.e., by abandoning traditional practical exercises such as unrelated preparative work and formal volumetric or qualitative analysis, and
d) By connecting "pure" and "applied" chemistry and relating chemistry to social and economic aspects of the world.

The course is divided into two sections, a basic course of 19 topics and one special study chosen from a group of five.

The basic list of topics is:—

Amount of substance; periodicity; the masses of molecules and atoms; the Avogadro constant; atomic structure; the halogens and oxidation numbers; the s-block elements and the acid-base concept; energy changes and bonding; carbon chemistry, part 1; intermolecular forces; solvation; equilibria: gaseous and ionic; carbon chemistry, part 2; reaction rates; equilibria: redox and acid-base systems; some d-block elements; equilibrium and free energy; carbon compounds with large molecules; some p-block elements.

The special study, which is expected to occupy a total of 4 to 6 weeks, is selected from:

Biochemistry; chemical engineering; food science; ion exchange; metallurgy.

Publications include two *Students' Books* (containing the 19 basic topics), separate books on the special studies, experiment sheets, four programed texts (the mole concept, oxidation numbers, names and formulae of carbon compounds, ethanol and other alcohols) as well as a book, *The Chemist in Action*, which is intended to help teachers and students understand the role of chemists in industry. There are also *Teachers' Guides*, film loops and overhead transparencies.

Nuffield A Level Physics

This scheme is divided into 10 Units, the first eight being described in separate students' and teachers' book while in the last two, which contain material not covered in existing textbooks, the students' and teachers' books have been combined.

The units are:

Materials and structure; electricity, electrons, and energy levels; field and potential; waves and oscillations; atomic structure; electronics and reactive circuits; magnetic fields; electromagnetic waves; change and chance; and waves, particles and atoms.

This scheme like the other A level schemes described above, is designed for a two year course with a time allocation of about seven periods per week (each of 40 minutes) or their equivalent.

In addition to the students' and teachers' books for the 10 units there are a number of 8 mm film loops, three sets of slides and a 16 mm film on *Change and Chance:* a model of thermal equilibrium in a solid. There are also books on Supplementary Mathematics—for those not taking an advanced course in mathematics—and one entitled *Physics and the Engineer*, a collection of reprints from *Science Journal.*

Nuffield A Level Physical Science

This scheme offers an integrated approach to physical science at the Advanced level. It has been designed on the basis of eight 40-minute sessions and in the hope that, at least initially, both a physics and a chemistry teacher will be jointly involved with the classes.

The structure of the course is as follows:

The basic course:

Forces, motion and energy; the elements of the second short period; kinetic theory and phase equilibria; some important chemical reactions; electricity and atomic structure; chemical equilibrium; intermolecular and interionic forces; structure and properties; an introduction to chemical kinetics; covalent bonds and the compounds of carbon; group relationships in the periodic table; elements of the d-block; simple harmonic motion and wave motion; electromagnetic induction and electrical oscillations; electromagnetic radiation;

The general options, of which each candidate is advised to choose two:

An introduction to thermodynamics; rate processes; rotational motion; the conduction of electricity; methods of purification and criteria of purity; molecular spectra and photochemistry; further organic chemistry.

The materials options, of which each candidate should choose one:

Metals; polymers; ceramics and glasses.

In addition there is project work which might involve a small investigation or the design and construction of a piece of equipment.

SCIENCE 5/13

Science 5/13 presents a new and important way of looking at the problem of helping children between the ages of 5 and 13 to learn about science. The trial materials have been tested in many schools throughout Britain and many others are already using the materials freely.

The project has been sponsored by the Schools Council, the Nuffield Foundation, and the Scottish Education Department. The materials are of help to teachers in assisting children to learn through the excitement of discovery at first hand. Various ways of doing so are discussed in the teachers' guide called *With Objectives in Mind.*

The books form a series of units to which teachers can turn for advice and guidance, for starting points and for background information, when children are working in subject areas covered by the books.

The units are related to stages in childrens' educational development rather than to their chronological ages. These stages cut across existing infant, junior and secondary school boundaries. Stage 1, for instance, is related to children who are thinking intuitively and to those who have reached the early stages of concrete operations; Stage 2 is concerned with those in whom the stage of concrete operations is well developed;

and Stage 3 is for those who are beginning to think with the aid of abstractions.

Some of the units that are already published or under trial are:

Working with wood; time; early experiences; science from toys; structure and forces; metals; change; mini-beasts; holes, gaps and cavities; trees; coloured things; ourselves; like and unlike; and plastics.

These materials are for the *teacher* not for the pupil.

This project developed from an earlier science project sponsored by Nuffield Foundation called Nuffield Junior Science Project (see next section).

NUFFIELD JUNIOR SCIENCE PROJECT

The Nuffield Junior Science Project is a large scale experiment in education in which young children have been introduced to the excitement of practical investigation and scientific observation. The record of what these children did during the course of their investigations forms the basis of the main publications.

Much of the project was concerned with working with and observing children. In this way, the project organizers endeavored to learn a lot about children, their behavior and how children learn. The result is a set of books intended to help teachers who want to use science as part of their work. The main purpose is to show teachers how science might be introduced into primary school work, how to get children doing practical work, how best to use books or films. There is no syllabus and no scheme of work as such. Rather there is a series of case studies which show the type of open-ended development that can arise from a variety of topics encountered in schools and their environment. The books themselves comprise two teachers' guides. The first sets out general educational thinking behind the project based firmly on the team's observations of children learning, in the classroom and out of it; the second illustrates the ideas and principles by means of 38 case histories. There is also a book on apparatus showing teachers how to make very simple apparatus from locally available materials, and a book on animals and plants. In addition, there are three teachers' background booklets entitled *Autumn into Winter*, *Science and History* and *Mammals in Classrooms*.

SCOTTISH SCIENCE

Physics

The Scottish Education Department issued a Circular in 1962 setting out an alternative syllabus in physics. This syllabus, with teaching notes, presented a scheme of work covering the four years of Scottish secondary schools leading to the Scottish Certificate of Education, Ordinary Grade, with a separate section dealing with work leading to the Higher Grade certificate.

The original Circular has been revised and was re-issued by the Scottish Education Department in 1968.

The general aim of both Ordinary and Higher Grade syllabuses is to present physics as a subject for the non-physicist as well as for those likely to go on to University to study physics or science.

The scheme of work in the first two years is now integrated into a general science scheme (described in Chapter 4 of this publication). However, the structure of the original alternative physics course is as follows:

Introducing Science
Laboratory techniques; experiments with observations and some conclusions.

The Basic Idea
Forms of energy; energy inter-conversions; energy converters in action.

Matter as Particles
Evidence for the fine division of matter; kinetic theory; applications.

Electricity
Electricity at rest; what is electricity? electricity in motion; opposing the current; heating by current; driving the current; introduction to electricity at home.

Making Heat Flow
Methods of heat transfer; problem situations.

Seeing and Hearing
The eye and light; the ear and sound.

Force, Work and Energy
Idea of force; work and energy.

Electricity and Magnetism
Dangerous and safe materials; electricity in the home; electronics; electric lighting; electro-magnetism; electricity supply.

For the next two years (grades 10 and 11), leading to the O Grade Scottish Certificate of Education, the structure of the course remains as follows:

Waves
Oscillations and waves; water waves; nature of light; electromagnetic spectrum; sound.

Newtonian Mechanics

Time; velocity and acceleration; vectors; inertia, force and motion; mass and weight; force as a vector; gravity and projectiles; momentum; conservation of linear momentum; mechanical energy.

Heat Energy

Temperature; temperature, heat and energy; universal conservation of energy; specific heat; latent heat; gas laws; qualitative kinetic theory.

Electron Physics

Electrostatics; circuits; magnetic effect of a current; electromagnetic induction; electronics.

The Nucleus

Radioactivity; Rutherford atom

For the Higher Grade certificate the course is structured as follows:

Mechanics and Properties of Matter

Kinematics; kinetics; pressure; kinetic theory.

Electricity

Electrical measurement; capacitance; electrical oscillations.

Optics and Spectra

Optics, waves, spectra, photons.

Models of the Atom

Alternate models examined.

This scheme of work, introduced as an alternative syllabus in 1964, is now taught throughout Scotland. No schools now offer the older, more traditional, syllabus. Books, based on the published syllabus by private authors, are now available for students and teachers.

The recently introduced physics course for the Certificate of Sixth Year Studies is an extension and development of the work of the earlier years, but requiring a more mathematical approach. The examination for this course includes assessment of a report on a project of experimental work undertaken by the student. The project is expected to be new to the student, but need not be original research. The assessment of the project, by his teacher in conjunction with an external evaluator, carries equal weight with the theoretical examination.

The main topics included in the theoretical portion of the course are:

Uniform motion in a circle; conservation of angular momentum; central force; gravitation; moment of inertia; motion and energy of a rotating body; simple harmonic motion; wave phenomena; interference and diffraction; Coulomb's law; electrical fields; potential difference; capacitance; effects and production of magnetic fields; electromagnetic induction; AC theory.

Chemistry

At about the same time as the alternative physics syllabuses were issued by the Scottish Education Department a similar circular for chemistry was published. This has also been revised (1968). The scheme is divided, as for physics, into the Ordinary Grade and the Higher Grade.

The principal topics for the O Grade are:

> Matter as particles; solvents and solutions; some common gases; hydrogen, acids and alkalis; the earth; atomic structure; chemical combination; activity in the electro-chemical series; acids, bases and salts; sulphuric acid; fuels and related substances; ammonia and nitric acid; foodstuffs and related substances; macromolecules.

At the Higher Grade the main sections are:

> Atoms; molecules and the mole; bonding and the periodic table; chemical reactions; carbon compounds.

As in the case of physics this scheme of work is now adopted in all Scottish schools and the original traditional syllabuses are no longer followed. A range of books based on the syllabus has been published.

As in physics, the chemistry course for the Certificate of Sixth Year Studies involves students in the conduct of an experimental research project. This project is assessed jointly by the student's teacher and an external examiner, and carries approximately 25 percent of the total assessment for the course. The theoretical work for the course is as follows:

> Revision of molar concept; energies in macroscopic systems; practical techniques in chemistry; spectra and structure; energy in relation to bonding; the carbon group elements; solution chemistry; electronic structure and the periodic table; the transition elements.

Biology

A new Scottish Certificate of Education syllabus in biology was not published at the same time as the physics and chemistry programs described above, but a new scheme is now available with the following main sections:

General Variation of Living Organisms

> Diversity of form; the idea of classification; types of habitat; effects of variation in biological habitat; the orderly investigation of living organisms; variation within an organism; complexity of structure within an organism.

The Cell

> Cell structure; cell division and cell growth; sub-microscopic structure of the cell;

Energy and Life

Energy and organic matter; ecological energetics; photosynthesis; respiration.

Processes of Life

Food and feeding; gas exchange between organism and environment; water and organisms; transport in organisms; shape, size and movement; perpetuation of the species; change in size and increase in complexity; integration and behavior.

Genetics and Evolution

Gametes and inheritance; the gene; evolution.

Interrelationship of Organisms with each other and with their Environment

Soil as an ecosystem; an organism as a habitat; man and micro-organisms; man's effect on his environment.

The Higher Grade syllabus contains an elaboration of certain of the above topics.

PROJECT TECHNOLOGY

In 1966 the Schools Council established a small feasibility project to find out how schools in Britain might be assisted to reflect in their curriculum the increasing importance of technology. Following this pilot trial it became apparent that action and co-ordinated development in this area were urgently needed. Many individual teachers had been developing, on their own initiative, activities which were essentially technological in character. These were attracting attention and their educational value was gaining recognition. Thus, on the basis of the pilot project, the Schools Council established in 1967 a major three-year curriculum development project entitled Schools Council Project Technology with the central purposes of

a) designing, testing, and arranging publication of teaching materials for schools wishing to include in their curriculum work in and about technology, and
b) stimulating outside support of all kinds for the schools.

The Schools Council subsequently agreed to extend Project Technology for a further two years until September, 1972, during which time the team concentrated on producing teaching material and stimulating appropriate developments in pre- and in-service training of teachers.

More than 1,000 schools, as well as a large number of Further and Higher Education institutions in Britain are associated with the project and with the central team based in Loughborough in the Midlands.

Teachers and others have been brought together in some 30 regional groups and sub-groups established to provide local support for school activities, to spread the philosophy of project technology and to assist with the trial of teaching materials.

Project Technology publishes a bulletin issued five times a year to schools associated with the project and other bodies and individuals connected with the project. The Bulletin was re-named *School Technology* in January, 1971 and it contains information and discussion of all aspects of the work of Project Technology and includes articles concerning a variety of technological activities in schools.

Among the teaching materials produced, at least in draft form, are the following:

Basic Electronics
A two or three year course for pupils of average ability, or a shorter more intensive course for teachers.

Control Technology
A two or three year course providing programmed units for pupils and a teachers' guide.

Photocell Applications
A pupils' and teachers' guide for use with average and above average students.

Fibres in A Level Chemistry
Pupils' booklets of background materials and worksheets.

Technology and Man
Published in three sections—*Communications, Environment* and *Energy*—each consisting of large multi-media integrated studies pack and teachers' guides. For students in grades 4 through 9.

History Units
Published in four sections, each consisting of a students' resource package and a teachers' guide—*Power of Steam, Age of Iron and Steel, The Textile Revolution,* and the *Making of Machines.*

In addition to these publications there are many other reviews and booklets as well as a range of films and slides. Project Technology also produces SATIS (Science and Technology Information Sources for Teachers) in conjunction with the Esso Petroleum Company Limited. This provides an abstracting service covering some 180 journals in the field of science, mathematics and technology.

BIOLOGY FOR THE INDIVIDUAL

This project arose from the Nuffield Foundation's Resources for Learning Project, begun in 1967.

The project consists of a series of texts intended for students working at their own pace. The material covers eight selected topics from the Nuffield *Biology* and *Combined Science* Courses and is intended for students aged 11-13 (Grades 7-9).

The books in the series are:

Introduction to the Series: Sorting Animals and Plants into Groups; How Life Begins; Movement in Animals; Support in Animals and Plants; The Problems of Life in Hot and Cold Climates; Microbiology 1; Microbiology 2; and *Plant Reproduction.*

In addition to the books for the students there are teachers' guides which include a complete pupils' text overprinted in a second color. They give page by page comments and advice on how to combine these texts with conventional teaching. Each book can be used independently of the others and can be separately fitted in to a normal science course whether Nuffield or non-Nuffield type.

Each book in the series contains between 30 and 80 fully illustrated pages containing clear instruction for the relevant practical work and other activities. Once the teacher has introduced a topic in his or her own way, the class can then work from the text at their own speed, either individually or with mutual aid.

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9

DIFFERENCES BETWEEN NATIONAL CURRICULUM PROJECTS IN BRITAIN AND THE UNITED STATES

To assess adequately the potential contributions of British science curriculum projects to continued United States developments, it is necessary to examine the differences between the characteristics of the educational systems and the curriculum projects of the two countries. The following section shows that differences in the initiation and methods of financial support are not important factors when considering the potential utilization of British experience in the United States. This realization allows the curriculum developer to concentrate on the essential difference: the degree of structure imposed upon the materials produced. It is this aspect of the British courses that is most important in the light of the trend in the United States toward unified, socially conscious courses (see Chapter 1).

Initial Pressures

The relative importance of the classroom teacher in project initiation, in the development of rationale, and in the writing of materials is one of the more noticable differences between the concurrent movements in the two countries. In almost all of the national curriculum projects in the United States the teacher members of the production teams have been recruited by the "outside experts" who initiated the projects. These outside experts in the early projects were primarily representatives of professional associations of scientists or associated with the university that acted as the supporting and administrative organization. The Chemical Education Materials Study and the Biological Sciences Curriculum Study, for example, were established as a result of concern for the quality of secondary school education by the American Chemical Society and the American Institute of Biological Sciences respectively.[1] Both of these projects were affiliated with universities: CHEM Study with the University of California at Berkeley, and BSCS with the University of Colorado at Boulder. But the university faculty did not initiate the projects.

The role of the classroom teacher in the development of CHEM Study is described in the project history.[2] "Outstanding" high school teachers, known to one or more of the professional chemists on the steering committee, were invited to participate in the planning and writing sessions, where they were valuable in providing counsel on level of difficulty of proposed concepts, the amount of material that could be satisfactorily covered in a one year course, and the manner of presentation of the textual material. Although each of the contributors to the history emphasizes that the high school teacher members of the production team played an extremely useful part and contributed greatly to the success of the study, all imply that the teacher's role was most valuable as a critic, not as an originator of text or ideas. Grobman's personal history of the development of the BSCS versions(3) supports a similar interpretation of the teacher's role in that project.

In addition to projects initiated by professional societies, there were a number of projects initiated by, and closely associated with, a particular university.(4) The University of Illinois Committee on School Mathematics, initiated because of dissatisfaction with the mathematics background of incoming freshmen, is an early example of a university taking responsibility for a curriculum project. Not all university-based projects are so closely identified with their own immediate "self interest." Minnesota Mathematics and Science Teaching Project (MINNEMAST), Intermediate Science Curriculum Project (ISCS) at Florida State University, and the Conceptually Oriented Program in Elementary Science (COPES) at New York University, are examples of projects associated closely with a particular university, but with a broader educational purpose. The role of the classroom teacher in these university-based programs varies. In some, for example ISCS, teachers and scientists are brought together in writing conferences in a manner similar to the professional association projects; in others, a small number of teachers are recruited to the full-time staff of the project.

A few of the more recently initiated national projects have used large teams of teacher-writers. These projects have tended to be based at a university (e.g., Harvard Project Physics), or at independent educational research and development organizations, (e.g., the Educational Research Council of America Science Program, Cleveland, Ohio). Some of the independent organizations have been established on foundations laid by an earlier curriculum project. BSCS, for example, is no longer closely associated with the American Institute of Biological Sciences, but is a curriculum development agent in its own right, conducting a diverse series of projects, including the development of a series of life science programs for educable mentally retarded children.(5) Educational Development Center, an outgrowth of the organization built up while the Physical Science Study Committee was producing its physics texts and apparatus, is responsible for a number of projects, including the Elementary Science Study and the Cambridge Conference on School Mathematics.

Regardless of the degree of teacher involvement in material production, classroom teachers were, of course, vital components of the testing, feedback, and revision phases of these projects.

In Britain, by contrast, the initiative for secondary school science curriculum reform came essentially from secondary school science teachers. As indicated in Chapter 3, the Association for Science Education (ASE) initiated the formation of committees to review the British school science programs, and, when funding was obtained, to prepare appropriate materials. In Scotland, the essential initiative was not so directly from classroom teachers, but from the science staff of the Scottish Education Department. Professional science societies and associations provided support, but were not the prime motive force.

The team responsible for the planning, writing, and testing of the Nuffield O level chemistry materials, for example, was composed almost entirely of experienced chemistry teachers from British schools. These teachers were able to recruit an advisory board that included practicing research chemists, administrators, and university faculty; but the prime responsibility remained in the hands of the teachers on leave from their schools to the project. In addition to the "headquarters team" other groups of teachers modified or developed, and then tested, chemistry experiments which were used in the *Sample Scheme* or published as *Collected Experiments* and assisted in the investigation of methods of evaluating students' progress. Many of the background books were also written by practicing teachers; others were solicited from scientists working in the appropriate field.

Nuffield *Secondary Science*, one of the last of the Nuffield projects to be published, has depended to a lesser extent on the contributions of practicing teachers. Although most members of the development team are associated with Colleges of Education, teachers in secondary schools were involved in a number of study groups at the colleges. Each group studied the implications of a small section of the Working Paper (see Chapter 6), decided on objectives for one theme, developed some content, and tested the ideas informally with their classes. This material provided the authors of the themes with a large number of ideas from which to plan their sections of the materials. A consultative committee was also established for *Secondary Science*, composed of university scientists, Her Majesty's Inspectors, College of Education staff, and representatives from industry.

With the establishment of the Schools Council as the primary curriculum development co-ordinating body in England and Wales, responsibility for much of the science curriculum development is passing into its hands. Thus the decisions about which of the proposed developments to support are made principally by representatives of teachers. But, as in the United States, much of the actual development of curriculum material, in all subjects, is the concern of relatively permanent curriculum development groups who make proposals for funding to authorities that can supply the necessary finance. Most projects listed in the 1970/71 Schools Council report, for example, were being conducted by organizations such as the National Foundation for Educational Research, the Centre for Applied Research in Education (University of East Anglia), The Chelsea Science Education Centre, and Colleges of Education.

Thus, although the initial Nuffield projects were the work of teachers, and the Director of the Nuffield Foundation could justifiably say that the publications "belong to the teaching profession as a whole"[6], the "grass-roots" activity appears to be decreasing, although occasionally teachers dissatisfied with materials available still initiate large scale curriculum projects. A recent example is provided by the Schools Council supported Continuation Project for Mathematics for the Majority.[7] The ASE continues to play an important role as a watchdog for the teaching profession and as a channel of communication of teachers' views.

The convergent evolution of the initially dissimilar patterns of curriculum reform in the United Kingdom and the United States can be interpreted as evidence that establishing a number of relatively autonomous curriculum development groups is an effective method of continuing the development of curriculum practice once the impetus and excitement of revolutionary change slows down. Both revolutionary models for curriculum improvement projects, whether it was the scientist or the teacher who took the initiative, have been successful in initiating change, but do not seem to have been viable during the post-revolutionary period of relatively slow curriculum change.

Program Flexibility

Any given teacher's influence on the syllabus that he uses with his classes falls somewhere on a continuum from no individual control to complete personal responsibility. The course content may be imposed by a body external to the school, whether an examination board such as the New York Board of Regents or a British GCE Examinations Board, or a local school district acting through a subject supervisor; it may be decided within the school, by the school faculty as a whole or by the teachers in each department; or the individual teacher may be responsible for the complete design of his own instructional program. Similarly, the instructional materials to be used may be imposed upon the teacher, by an external textbook adoption committee or by school board policy; or the teacher may have absolute freedom to choose or construct his own materials.

These two continua are not necessarily parallel, for it is possible to teach an externally imposed syllabus by using materials developed by the individual teacher. This is clearly shown in the Nuffield projects, where the physics and chemistry O level materials were designed to provide teachers with tested resources from which they could model their own courses to prepare students for externally prescribed syllabuses. Contrast this situation with the early United States science course improvement projects which, although the teachers were not expected to teach to a syllabus designed by an external examination body, tended to produce a complete course. The teachers' guides to these courses provided detailed instructions on sequence and on instructional procedure. To some extent, the projects attempted to foresee all difficulties and produce a "teacher proof" curriculum,[8] supplying all necessary texts, pupils' manuals, and test and evaluation exercises.

There is some evidence that the United States projects proceeded in this way because the developers felt that extensive sets of resource materials would not be effective in upgrading classroom science instruction. The BSCS, for example, found that

> a series of independent units would not be generally useful to teachers as we had originally thought. Very few teachers indicated to us that they would like to assemble independent units in order to tailor-make their own courses. Secondary school teachers are confronted with exhausting and crowded schedules, and most of those with whom we had spoken stated that they would much prefer to experiment with a complete course organized by a group of competent biologists.[9]

To avoid the implication that there was one *best* biology course, the BSCS then developed three versions, so that teachers would have an opportunity to choose materials suited to their own special situations. Similarly, CHEM Study developed because officers of the American Chemical Society felt a need to have more than one version of a chemistry course funded by the National Science Foundation. The Chemical Bond Approach (CBA) had been established earlier, and it was felt that another approach should be made available.[10] This desire to promote flexibility by providing choice between complete courses also led to the release of CHEM Study materials for the production of three additional versions by other authors.[11]

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There have been exceptions to this general pattern of United States projects producing complete packages for highly structured courses. Elementary Science Study (ESS) for example, has produced a large number of units which schools can arrange in different sequences to suit their own special conditions. The printed materials available are primarily intended for teachers and describe the use that can be made of apparatus and aids developed for the project. Harvard Project Physics is also far less structured than the first generation United States science curricalum projects. However it is still a more structured course than most of the Nuffield projects.

Although the British projects also range from the relatively highly structured syllabuses of the Scottish projects (but without associated texts written by the course developers) to sets of teachers' guides that do not imply any particular course (e.g., Nuffield *Secondary Science)*, most of the programs are toward the "flexible" end of the range. Except for the O level biology project, the early British projects did not produce student textbooks. The teachers' guides were designed to be resources to assist teachers plan their programs and to use effectively the apparatus and other aids, including background booklets and film loops, developed by the project. (For the later A level programs, which include material that would be considered college-level in the United States, some student texts were also produced.)

Although most of the British projects emphasize the importance of teachers constructing courses to suit their own situations, the projects vary in the extent to which a particular course is *implied* by the structure of the teachers' guides. The range can be seen in the projects described in Chapters 5, 6 and 7. The "Sample Scheme" approach, used by the Schools Council Integrated Science Project in its *Patterns* materials, is quite highly structured. The teachers' guides, and the associated pupils' and technicians' manuals, are written with one particular version of a course that would meet the specified objectives in mind. Nuffield *Combined Science*, although written in a possible teaching sequence, also contains specific suggestions of possible alternate links between each section (see Fig. 5.4), and has attempted to show teachers that other sequences will "work" in the classroom. The most flexible scheme, Nuffield *Secondary Science*, would be almost impossible to use as a viable course by commencing at the beginning of Theme One and working sequentially to the end of the series. *If* a teacher wants to use a sequence suggested by the course developers, he has to choose from twelve alternate pathways.

Even the unstructured materials are prepared from a particular point of view: in the case of *Secondary Science* it is an advocacy of student investigation, an emphasis on social implications, and a concern for the relevance of the materials to everyday life. To this extent a teacher choosing to base his course on resource materials produced by a specific project is adopting its viewpoint, even if there is no monolothic course to follow.

Financial Support

In the United States most of the financial support for the curriculum developments in science and mathematics has been supplied by the Federal government, principally through the National Science Foundation and the Office of Education. The Foundation was given power to assist science education development when it was established in 1950[12], but it was not until the 1957 launching of Sputnik I that rapid proliferation of science course improvement projects occurred. The implementation of these courses was assisted by funds provided under the National Defense Education Act.

In the United States, therefore, much of the curriculum revision was in response to an apparent national need:

> The sudden realization of the importance of scientific education to American life and safety . . . [indicates that] a greater pool of scientifically-minded citizens and of scientists is needed to enable the free world to regain and then maintain a position of scientific superiority in the cold world era.[13]

In Britain, on the other hand, nationalistic reasons had little influence on the development of new programs. As indicated in Chapter 3, the government refused support for the revision of science curricula, and it was the ability of science teachers to convince the Nuffield Foundation of the pedagogic reasons for course revision that led to the British science curriculum improvement projects. Concurrently the Scottish Education Department supported similar developments by using its own officers and Scottish teachers.

At present, curriculum development in both the United States and Britain is financed predominantly from government sources, with some contribution from private philantrophic foundations. The projects funded are selected mainly by the Schools Council, the U.S. Office of Education, or the National Science Foundation after an evaluation of current priorities. The present differences between the two countries are essentially in the degree of direct government control of the funding agencies. In the United States the NSF and the Office of Education are parts of the executive branch of government. The Schools Council, by contrast, is an autonomous, self-governing association of educational agencies (LEAs) controlled by a council composed of a majority of teacher members, with government representatives in a minority. The funds distributed by the Schools Council are not under direct government control after the Council's allocation has been received from the Treasury, the LEAs and other sources.

10

IMPLICATIONS FOR THE UNITED STATES

The comparisions in Chapter 9 indicate that the fact that there were differences in the origin and financing of the British and United States science course improvement projects has little significance for future United States projects.

The role of British teachers in establishing the Nuffield projects was spontaneous, and a deliberate administrative decision to produce teacher-developed courses is unlikely to be successful. Dedication and enthusiasm cannot be imposed by fiat. However, the British experience has demonstrated that successful revolutionary course development projects do not require practicing scientists to play the prime role: funding agencies need not look askance at large scale projects dominated by experienced, well qualified teachers. Moreover, if the thesis concerning a convergent evolution towards specialized curriculum development agencies is correct, neither the teacher-dominated nor scientist-dominated team is a necessary requirement for future successful developments. Both the Nuffield and NSF groups formed a revolutionary thrust; they are not appropriate organizational analogues for the codification of curriculum development techniques.

Similarly, the differences between sources of initial financial support were determined by a complex of social and political factors, and are not likely to provide guidance in planning future projects in either country. Indeed, it is likely that curriculum improvement would have occurred in the United States without the impetus provided by Russian space prowess. Although this is an untestable hypothesis, the fact that the National Science Foundation provided funds, *before* October 1957, (1) for the Massachusetts Institute of Technology study-group that eventually gave rise to the Physical Science Study Committee suggests that the climate for reform already existed. Sputnik may have been merely an effective catalyst.

In the discussion that follows it is assumed that there *is* a place for continued curriculum development by specialized units. We do not deny that the individual teacher can and should develop some of his own instructional units *de novo;* but we assume that no one teacher will have sufficient resources—of time, academic background, libraries, audio-visual technicians, artists and designers, and unbiased evaluators—for him to develop and test *all* of the materials for all of his classes. Curriculum development units or teams have these facilities, and are potentially able to delay release of their materials until evidence of their worth is obtained. These organizations are also more likely to have the time to update their products in light of feedback from far more classes and students than are available to the individual teacher.

Structural Models?

It is the *structure* of the British courses that has most relevance to future United States curriculum development. A project modeled on the structure of *Secondary Science*, for example, would meet most of the organizational criteria suggested by the Callaway Gardens conferees.(2) It would be flexible, provide teachers with tested resources for use in a variety of situations, and enable courses to be tailored to individual student needs and interests.

Possible implementation strategy. It would not be necessary to create a completely new curriculum development center for the task of producing materials with a similar structure to British projects. To produce a program modeled on *Secondary Science*, for example, existing organizations could cooperate, each concentrating on those aspects for which it has most competence. It would be essential, however, that there was a clear unity of philosophy and of implicit instructional strategies in the materials produced. If a co-ordinating secretariat, possibly composed of representatives of the individual project components, were responsible for the establishment of these guidelines, and for the conduct of trials of a number of different sequences of the units produced, it could be possible to base the development of the materials in the existing curriculum development centers. This would have additional advantages, since, as was the case in Britain, it may be advantageous to base many of the learning activities on apparatus and materials developed for the first generation projects, both to minimize expense in equipping schools and to reduce the amount of teacher reorientation required.

Programs assembled from materials all prepared from the same philosophical position are more likely to succeed than individual courses constructed by taking components from a diversity of materials, each prepared for different long-term goals. These different programs could be assembled by the project, and published in an overall guide to the materials in the same manner as the twelve possible programs of *Secondary*

Science, (see Chapter 6, especially the appended course examples), or they could be assembled by the school district or individual teacher. Some individual integrated courses are being constructed from components of other courses in the United States at present, but from sections of courses originally designed to be parts of separate monolithic curricula. If a course could be made from materials designed originally to fit into a number of sequences, there would probably be more local curriculum initiative, similar to that used by the Dade County (Florida) School Board in developing the instructional material needed for their quinmester program.[(3)]

There is, of course, no need to limit development of extensive resource materials to one project. It may be advantageous to finance a number of sets of materials, some based upon the assumption that students will be heavily involved with their teachers in co-operative planning of the details of their own learning experiences, some assuming a relatively teacher directed model, and others based upon self-paced and/or multiple pathway styles of individualized instruction. This diversity would enable any teacher to develop for his pupils a course compatible with his own teaching style: there is evidence that teachers are more effective when using materials closely related to their own philosophy and pedagogic preferences.[(4)] Sets of resources built upon alternate views of teaching can be designed with common long--term goals in mind: alternate methodology does not necessarily imply different long-term objectives.

In addition to the macroscopic model for the development of flexible materials developed by *Secondary Science*, and, to a lesser extent, by *Combined Science*, the British programs provide a microscopic model of the fine structure of materials based heavily on student investigation. The second generation British projects can serve as detailed guides for United States groups commencing similar projects, particularly in the manner of relating laboratory activity to the out-of-school world and the methods of writing teachers' guides without forcing a teacher slavishly to follow a script written by the developers.

Potential obstacles. The greatest obstacle to successful implementation of courses modelled on the structure of British programs, with their heavy emphasis on preparation of materials for teachers and less concern for writing pupil textbooks, is likely to be teachers' expectations for new curriculum materials. The present generation of science teachers in the United States, about half of whom have entered teaching since the introduction of the initial science course improvement projects[(5)] have come to expect a curriculum adoption decision to involve the acceptance of a textbook-laboratory manual-teachers' guide package. Material that originates from an individual publisher's initiative, as well as that from NSF or U.S. office of Education funded science course improvement projects, is now likely to come in the form of a "package deal." Publication in this form becomes impracticable if the idea of individually constructed courses produced from a set of related resource materials is accepted. Publication of textbooks based upon even a small number of the possible sequences drawn from a course similar to *Secondary Science*, for example, is unlikely to be economically viable. It might be possible to publish details of tested experiments on separate sheets, somewhat in the manner of the Scottish Integrated Science worksheets although not necessarily providing spaces for results and answers, so that a teacher could order class sets of those experiments around which he planned his course. Even if this method of publication of pupil laboratory and field guides is used, the teacher will have to become adept at selecting, sequencing, and synthesizing separately published resource materials.

This need has implications for teacher education, both pre- and inservice. To obtain maximum benefit from a flexible set of materials, teachers must have competence and confidence in planning unique courses. Their role must be seen to change from that of a dispenser of instruction prescribed by the developers of the monolithic course that the teacher adopted, to the prescriber and dispenser of instruction chosen from a stock of compatible tested activities. He will need to be able to choose the significant reference materials, including short background booklets, for student reading; the appropriate student laboratory and field activities; and the relevant methods of fostering out-of-school open-ended and open-sided individual activities. These skills will be necessary for any type of modular program—whether teacher- or student-centered—if a serious attempt is to be made to build programs uniquely suited to students of different social, geographic, and intellectual backgrounds.

Minimization of structural obstacles. Further monolithic curricula will not be suitable vehicles to achieve the individualization goals; but sudden introduction of very unstructured materials is likely to be difficult due to teacher inexperience with course structuring. Data from a survey of elementary schools in two regions of the United States suggests that unstructured courses are less likely to be adopted than science courses with a definite sequence. Elementary Science Study materials, which are sets of relatively independent resource materials, were rarely adopted (less than 5% of the schools sampled in any state in either region), whereas the relatively highly scripted *Science—A Process Approach*, was more readily adopted (up to 11% in one state)[6]. The degree of structure is not the only variable influencing adoption, but these data suggest that the resistance to assembling courses noted by Grobman may still exist.

The initial shock of unstructured materials may be decreased by publishing teachers' guides for several "sample schemes" drawn from the resource materials. Within these schemes, which we envisage to have a structure similar to *Combined Science*, alternate possible sequences would be shown. A teacher could, initially, use the published sequence, then use a different pathway, which he felt was more suitable for his students, from the sample scheme, finally progressing to completely structuring his own unique course from the full set of resource materials, not just those included in the sample schemes.

Teachers are not, of course, all at the stage where they must have a course spelled out in detail. Many are now organizing their own courses from materials published by a variety of sources. Therefore, teachers' resources published by a curriculum project of the type being discussed here should include numerous unsequenced units as well as several sample schemes. Until teachers in the United States come to expect to assemble their own programs, we suggest that curriculum materials be published in a manner similar to a combination of the *Secondary Science* resource quarry and sets of materials with the flexible sequence of *Combined Science*. An overall teachers' guide to the full range of resources produced by the project, including audiovisual aids and background booklets, will also be necessary.

Content Models?

The second generation British science curriculum projects described in this monograph integrate the natural sciences, reflect a concern for the social implications of science, and attempt to avoid barriers between the social and natural sciences. *Secondary Science*, for example, is firmly based upon the experiences of children in the real, technological world where science affects and is affected by societal value systems; even for the relatively academic pupil the Schools Council Integrated Science Project emphasizes the socially relevant science skills and knowledge. Such courses meet many of the content criteria for modern science courses implied by Hurd[7], and it is likely that they could serve as *models* for the content of future United States projects.

It is emphasized that these materials could serve as *models*, not as curriculum materials for *adoption*. The more successful the projects are in relating the science principles to the immediate world of the child, the less chance there is of successful transplantation to a different country, with its different cultural setting, social problems, and implicit values. Although there are some similarities between the United States and

Britain, the differences that do exist would mitigate against a direct implementation of suggested teaching sequences in the United States. Even the relatively simple differences in weights and measures would make the British material unreal for United States children: Britain is in the process of changing to a metric system of measurement for domestic use, and the consistent use of SI units in the materials is not as alien to British students who see paint, timber, and some fabrics already being sold in the units used in the science classroom as it would be to United States students, for whom it could be an example of the unreality and mystique of science.

This is not to say that we feel that United States developers could only use the content of British programs as models of methods of bridging subject areas within the natural sciences and between the natural and social sciences. The materials contain a wealth of ideas for teaching and learning activities, many of which are not current in the United States. Any developer of curricula needs to be supplied with as many sources of ideas as possible. He may merely modify existing products, translating them into suitable language and supplying local examples; or they may serve as a stimulus of a completely new idea. For this reason the British science curriculum projects would serve a useful purpose in the library of professional curriculum developers and in the library of schools developing their own programs. But teachers should not expect to be able to use the activities contained in these publications without modification, particularly those activities which bridge the natural and social sciences.

In addition to their use as a source of ideas for the development of classroom, field, and home activities, the British materials will serve as a useful source of supplementary instructional material. The plans for the construction of apparatus associated with a number of the projects; the background readers and data book produced for Nuffield O level *Chemistry;* some of the film loops and other audiovisual aids; and the test items prepared for *Secondary Science*, Schools Council Integrated Science Project, and by the Scottish Working Party on science, will serve as aids that can be used as they stand. A judicious selection of the background readers for Nuffield *Chemistry*, for example, could supplement existing chemistry courses, and may serve as a basis for the chemistry components of integrated science courses to be developed.

Implications from School Organization

The British materials are not written from the viewpoint of a school program where separate science courses in the last three years of secondary school are arranged sequentially to follow general or health science in the years equivalent to American junior high school. The early projects produced materials for concurrent biology, chemistry and physics programs throughout the secondary school years; the newer integrated programs produced resources for courses expected to extend over more than one school year (see Chapter 3). It is likely, therefore, that the British experience will be more directly applicable to schools which have departed from the traditional biology-chemistry-physics sequence of courses in the high school years, or for those planning to do so. The general absence of an institutional division between the equivalent of the junior high school grades and the senior high in Britain suggests that there may be some difficulty in adapting the British experience of science programs organized within one science department for the complete post-elementary school experience to the United States.

These difficulties would arise mainly from the attempt to bodily transfer the British materials to a United States school system. As we have indicated previously, we do not think that that is a viable use of the British materials; we believe that they are more suitable as models of content and organization than as intact teaching programs.

There are some points that would need to be kept in mind if a school system attempted to model courses on the flexible British programs. If sets of resource materials were prepared for United States conditions on the assumption that a science program would extend over all the high school years, for example, any school assembling a program from these components must recognize that it would be a major alteration of the school tradition to have most students in science classes until their senior year. Initially courses would need to be very carefully planned so that each unit (year, semester or other module) of the sequence was adequately balanced and formed an intellectually satisfying whole. Repetition should be avoided in the sequence of units taken by any pupil, except for the minimal revision of basic concepts that may be necessary for the topics under discussion.

The junior high school years would not present the same problem, as it is more reasonable to expect these students to take a full sequence of science.

The preceeding discussion has assumed that the schools will be organized so that teaching will take place within subject areas, although connections between the subjects may be emphasized whenever possible. If these traditional boundaries are abolished, and teaching is organized on the basis of general studies around a number of "courses" which cut across subject borders, the only British model described in this volume that would be directly applicable would be the Scottish Second Cycle materials. These materials, described in Chapter 4, are not detailed plans, but are suggestions for possible science components for a number of courses. The production of resource materials specifically for such courses would be a mammoth undertaking, unless the spirit of completely unique programs for each school were so modified that a small number of sample schemes with input from the natural and social science, the humanities, the arts, and the vocational programs were produced. Schools wishing to follow this route would not be able to draw upon one of these British models, but would have to look elsewhere, or synthesize their own materials from a large number of sources, including world wide curriculum development projects in each of the special subject areas.

Summary

Although the British materials described in this volume contain some ideas that will be useful in United States classrooms as they were initially written, and although there are a number of supplementary materials that can be drawn upon as they stand, the most important contribution that these overseas materials can make toward the improvement of curriculum practice is as models of viable alternatives to the prevailing highly structured monolithic package of textbook-laboratory manual-teachers' guide. Models of various degrees of flexibility are provided by the four programs described in detail, so that school districts, teachers, or curriculum developers can choose and build upon the model with the degree of structure appropriate to their own stage of professional development.

ERIC

FOOTNOTES

Chapter One

[1] Paul DeHart Hurd, "Emerging Perspectives in Science Teaching for the 1970's." *ECCP Newsletter* 4(8):1-4, Spring, 1972.
[2] Ibid., p. 1.
[3] Ibid., p. 3.
[4] Ibid.
[5] Ibid., p. 5.
[6] Ernest Burkman, "New Directions for the High School Science Program," *The Science Teacher* 39(2):42-44, 1972.
[7] Ibid., p. 43-44.
[8] Ibid., p. 43.
[9] Ibid., p. 44.

Chapter Two

Further information concerning the educational systems described in this chapter may be obtained from *Education in Britain* (London: Reference Division, Central Office of Information, November, 1971).

Chapter Three

[1] Science Masters' Association/Association for Women Science Teachers, *Biology for Grammar Schools, Chemistry for Grammar Schools,* and *Physics for Grammar Schools* (London: John Murray, 1961).
[2] Available as *School Science and General Education* (Cambridge: Association for Science Education, 1965).
[3] Op. Cit.
[4] *Schools Council Report 1970/71* (London: Evans/Methuen Educational, 1971).
[5] See S. T. Bailey, "Teachers Centers: A British First," *Phi Delta Kappan* 53:146-149, 1971.

Chapter Four

[1] Scottish Education Department, Consultative Committee on the Curriculum, *Curriculum Papers, 7. Science for General Education: for the First Two Years and* the *Early School Leaver.* (Edinburgh: H.M.S.O., 1969), p. 9.
[2] *Ibid.*, p. 16.
[3] *Ibid.*, p. 100.
[4] Working Party on Science, *Integrated Science Course, Memoranda for Teachers, Sections 9-14 (Year II),* (Edinburgh: Scottish Education Department, n.d.), p. 24.
[5] *Ibid.*, Sections 1-8, p. 18.
[6] *Curriculum Paper 7*, p. 18.
[7] *Memorandum for Teachers*, Sections 9-14, p. 21.
[8] *Curriculum Paper 7*, p. 75.
[9] *Ibid.*, p. 23.
[10] Duplicated Information Sheet on SSSERC, June, 1971.
[11] *Curriculum Paper 7*, p. 22.
[12] *Ibid.*
[13] *Ibid.*

14 Bloom, B.S. (Ed.), *Taxonomy of Educational Objectives. The Classification of Educational Goals: Handbook I Cognitive Domain* (New York: David McKay, 1956.)
15 *Curriculum Paper 7*, p. 24.
16 Scottish Education Department, *From School to Further Education* (Edinburgh: H.M.S.O., 1963).
Scottish Education Department, *Raising of the School Leaving Age: Suggestions for Courses* (Edinburgh): H.M.S.O., 1966.)
17 *Curriculum Paper 7*, p. 32.
18 Scottish Education Department, *Science Topics for Third and Fourth Year Non-S.C.E. Courses* (Duplicated, no date.)
19 *Curriculum Paper 7*, p. 33-34.

Chapter Five

1 *Nuffield Combined Science Teachers' Guide II* (London: Longman; and Harmondsworth: Penguin, 1970), p. 80.
2 *Ibid.*
3 *Nuffield Combined Science Teachers' Guide I* (London: Longman; and Harmondsworth: Penguin, 1970), p. xii.
4 *Ibid.*
5 *Ibid.*, p. xvii.
6 *Ibid.*, p. 115.
7 *Ibid.*, p. 25.
8 *Ibid.*, p. 24.
9 *Ibid.*, p. 134.
10 *Ibid.*, p. 240.
11 *Ibid.*, p. 244.
12 *Ibid.*, p. 3.
13 *Ibid.*, p. vx.
14 *Ibid.*, p. 116.
15 *Teachers' Guide II*, p. 210.
16 *Teachers' Guide I*, p. xvii.
17 *Ibid.*

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1 The Nuffield Foundation, *Nuffield Secondary Science: Teachers' Guide*. (London: Longman, 1971), p. 3.
2 [L. G. Smith],*Science for the Young School Leaver*, Schools Council Working Paper No. 1 (London: H.M.S.O., 1965).
3 Ibid., p. 4.
4 Ibid.
5 *Teachers' Guide*, p. 15.
6 Ibid., p. 17.
7 Ibid., p. 9.
8 Field 5.4 refers to Field 4 within Theme 5. (See Table 6.1.)
9 Edgar Howard, *Nuffield Secondary Science, Theme 4: Harnessing Energy* (London: Longman, 1971), p. 77.
10 Dennis Fox, *Nuffield Secondary Science, Theme 3: Biology of Man* (London: Longman, 1971), p. 261.
11 W. Richardson and J. K. Tollyfield, *Nuffield Secondary Science, Theme 6: Movement* (London: Longman, 1971), p. 84.
12 *Teachers' Guide*, p. 19.
13 Ibid., p. 20.
14 Ibid.
15 Edgar Howard, *Nuffield Secondary Science, Theme 5: Extension of Sense Perception* (London: Longman, 1971), p. 140.

[16] *Teachers' Guide*, p. 19.
[17] G. R. Meyer, "Reactions of Pupils to Nuffield Science Teaching Projects Trial Materials in England at the Ordinary Level of the General Certificate of Education," *Journal of Research in Science Teaching* 7:283-302, 1970.
A. M. Lucas and N. A. Broadhurst, "Changes in Some Content-free Skills, Knowledge, and Attitudes During Two Terms of Grade 12 Biology Instruction in 10 South Australian Schools," *Australian Science Teachers' Journal* 18(1):66-74, 1972.
[18] *Teachers' Guide*, p. 20.
[19] George Wigglesworth, *Nuffield Secondary Science, Theme 2: Continuity of Life* (London: Longman, 1971), p. xii.
[20] *Teachers' Guide*, p. 28.
[21] Ibid., p. 3.
[22] Ibid., p. 26.

Chapter Seven

[1] See Chapter 3, footnote 4.
[2] Schools Council Integrated Science Project, *Draft Working Paper* (Duplicated, n.d.), p. 1.3.
[3] Ibid., p. 6.3.
[4] Ibid., p. 6.4.
[5] Ibid.
[6] The processes of science developed in SCISP are: observing, classifying, using numbers, measuring, using space-time relationships, communicating, predicting, inferring, defining operationally, formulating hypotheses, interpreting data, controlling variables and experimenting.
[7] William C. Hall, "The Schools Council Integrated Science Project," *Aspects of Education, Journal of the Institute of Education, the University of Hull*, Number 12, July, 1971. 81-85, p. 83.
[8] *Integrated Science Bulletin*, No. 3, p. 5.
[9] Schools Council Integrated Science Project, *Patterns: Teacher's Guide 1A* (London: Schools Council Publications. Duplicated. Trials Verson. 1971), p. 2.1.
[10] Schools Council Integrated Science Project, *Patterns: Teacher's Guide 6* (London: Schools Council Publications. Duplicated. Trials Version. 1971), p. 17.1.

Chapter Nine

[1] Richard J. Merrill and David W. Ridgway, *The CHEM Study Story: A Successful Curriculum Improvement Project* (San Francisco: Freeman, 1969). Chapters 1 and 2, passim.
Arnold B. Grobman, *The Changing Classroom: The Role of the Biological Sciences Curriculum Study*. BSCS Bulletin Number 4 (New York: Doubleday, 1969). Chapter 2, passim.
[2] *CHEM Study Story*, Chapter 2.
[3] *The Changing Classroom*, passim.
[4] Details of the projects mentioned may be found in J. David Lockard (ed.), *Seventh report of the International Clearinghouse on Science and Mathematics Curricular Developments* (College Park: Commission on Science Education, American Association for the Advancement of Science *and* University of Maryland, 1970).
[5] See *BSCS Newsletter*, Number 46, 1972.
[6] Brian Young, preface to the Nuffield O-level project guides, (e.g., *Nuffield Chemistry, Introduction and Guide* (London: Longman; and Harmondsworth: Penguin, 1966). p. v).
[7] P. Kaner "Teachers Can Write," *The Times (London)Educational Supplement*, November 5, 1971.
See also various issues of *Newsmaths*, the newsletter of the continuation project.

[8] An interesting insight into the perceived role of the curriculum development project as the source of a complete teaching prescription is contained in an American review of the Nuffield *Biology* materials: "The weakest part of the Nuffield curriculum is the teacher's guides which . . . completely fails (sic) to provide teaching strategies for the implementation of the stated inquiry goals. The usefulness of the guides could have been greatly increased by the addition of teaching strategy, assignment schedules, and more suggestions for acquisition and use of supplementary materials." (Norris A. Anderson, "Nuffield Foundation Biology—A Review." *The American Biology Teacher* 30:23-25, January, 1968, p. 24).

[9] *The Changing Classroom*, p. 62.

[10] *CHEM Study Story*, p. 1.

[11] Ibid., Chapter 5.

[12] ". . . it shall be one of the objects of the Foundation to strengthen basic research and education in the sciences." United States Code, 1964 edition, Title 42, Chapter 16, Section 1862 (b), quoted in Alvin Renetzky ad Barbara J. Flynn (eds.) *NSF Factbook* (Orange, N.J.: Academic Media, 1971), p. 389.

[13] Joseph S. Roucek (ed). *The Challenge of Science Education* (New York: Philosophical Library, 1959), p. viii.

Chapter Ten

[1] C. Russell Phelps, "Orientation, Purpose, and Scope of NSF Teacher Training Programs," National Science Foundation, Washington, D.C., Memorandum to members of the Divisional Committee for Scientific Personnel and Education, July 25, 1963, p. 10. This memo also reflects the interest of the National Science Foundation in upgrading the subject matter preparation of science teachers through the support of Institutes in the pre-Sputnik era: Summer Institutes commenced in 1953; Academic Year Institutes in 1956-57, and Inservice Institutes in Spring, 1957. (See pages 1-4.)

[2] See Chapter 1 for a summary of the criteria reported in Ernest Burkman, "New Directions for the High School Science Program." *The Science Teacher* 39(2):42-44, February, 1972.

[3] See *Status-Projections-Implications of the Quinmester Program* (Miami, Florida, Dade County Public Schools Division of Instruction, April 1971), for a discussion of this program. Examples of the method of specifying activities, chosen from a variety of texts and teachers' guides, that are compatible with specified objectives may be found in Betty Lou McCallum and Leonard P. Foster, *The World of Animals* (Miami, Florida: Dade County Public Schools Division of Instruction, 1971) and Barbara A. Silver and Charlotte Miller, *Cell Biology* (Miami, Florida: Dade County Public Schools Division of Instruction, 1971). There are a very large number of similar teachers' guides and courses outlines prepared for the Dade County schools.

[4] Patricia E. Blosser and Robert W. Howe, "An Analysis of Research Related to the Education of Secondary School Science Teachers." *The Science Teacher* 36(1):87-95, January, 1969. See particularly p. 89 and the citations of the work of Kochendorfer (p. 87) and Barnes, (p. 89).

[5] Long Fay Chin, "A survey of Science Teaching in the Public Secondary Schools of the Great Lakes Regions and Far West Regions of the United States in the 1970-71 School Year" (Ph.D. Dissertation, The Ohio State University, 1971), Tables 91 and 92. In a sample of schools, proportionally stratified on enrollment, over 48% of the science teachers had less than ten years experience.

[6] Jerrold William Maben, "A Survey of Science Teaching in the Public Elementary Schools of Two Selected Regions of the United States During the 1970-71 School Year" (Ph.D. Dissertation, The Ohio State University, 1971), Tables 45 and 46.

[7] See Chapter 1 for a summary of the criteria identified by Paul DeHart Hurd, "Emerging Perspectives in Science Teaching for the 1970's." *ECCP Newsletter* 4(8):1-4, Spring, 1972.

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The publications of the British science curriculum development projects referred to in the text are listed, by project, in this bibliography. Materials not sponsored by the projects are not listed, although some are referred to in the footnotes to the appropriate chapters. This procedure has been followed to avoid unintended bias when selecting independently produced texts and teachers' guides that purport to follow the approach recommended by a particular project.

Projects are listed in the order in which they are described in the text. Publishers addresses are collected at the end of the bibliography.

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NUFFIELD COMBINED SCIENCE

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Nuffield Combined Science: Teachers' Guide II, Sections 6-10.

Nuffield Combined Science: Teachers' Guide III.

Nuffield Combined Science: Pack I Activities.

Nuffield Combined Science: Pack II Activities.

Film Loops.

African Clawed Toad—Injections and Pairing
Male Rat—Finding the Reproductive System
Female Rat—Finding the Reproductive System
A Variety of Animals and Movements I
A Variety of Animals and Movements II
Birth—Calf and Baby (black and white)
Growth of a Bean Shoot—Measurement
Contact Electricity in Industry
Detergency
Desalination
A Fish—Movement in Slow Motion
A Frog—Movement in Slow Motion
Buoyancy of Gases
Fertilization in the Flowering Plant
Gases of the Air at Work
Hydrogen
Air in Motion
Large Scale Forces
Manufacture of Steel

(Some of the film loops had not been published by Summer, 1972.)

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Artificial Insemination
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The Breeding of Roses
Car Crash in Slow Motion
Cereal Husbandry
Chick Embryo: I
Chick Embryo: II
Cleaning Mechanism of the Lungs
Earthquakes
Energy in Action
Formation of Fossils
Geological Time Scale: I
Geological Time Scale: II
Gliding and Soaring
The Growth of Humans
Human Hormones
Investigatory Dissection of the Pigeon
Laboratory Precautions in Microbiology
Looking at Changes
Motor Skills in Primates
Movement of a Joint
Parental Care in Wild Animals: 1
Parental Care in Wild Animals: 2
Pig Husbandry
Pouring and Streaking (microbiological plates)
Progeny Testing
The Results of Selective Breeding of Two Varieties of Hens
Some Solutions to World Food Problems
Swabbing and Seeding (microbiological plates)
Techniques of Collection in a Fresh Water Habitat
Volcanoes
World Food Problems

Photographs and Slides.

The Earth's Crust (set of 30 slides)
Set of 42 slides to accompany Field 8.2
Weather Satellite Photographs (set of 17 slides)
Energy in a Plant: X-rays: Car Crash (pack of slides for Themes 4, 5, and 6)
Embryology, Set of 22 slides for Field 2.2
Set of 33 photographs and line drawings for sections 2.32 and 2.33

THE SCHOOLS COUNCIL INTEGRATED SCIENCE PROJECT

Commercially published material will not be available until spring of 1973 when the Longman Group will begin publishing pupils' manuals, teachers' guides, and technicians' manuals under the general title *Patterns*.

ERIC

NUFFIELD O LEVEL BIOLOGY

All materials for this project are jointly published for the Nuffield Foundation by the Longman Group and Penguin Books, from 1966.

Nuffield Biology: Text I: Introducing living things
Nuffield Biology: Text II: Life and living processes
Nuffield Biology: Text III: The maintenance of life
Nuffield Biology: Text IV: Living things in action
Nuffield Biology: Text V: The perpetuation of life
Nuffield Biology: Teachers' Guide I: Introducing living things
Nuffield Biology: Teachers' Guide II: Life and living processes
Nuffield Biology: Teachers' Guide III: The maintenance of life
Nuffield Biology: Teachers' Guide IV: Living things in action
Nuffield Biology: Teachers' Guide V: The perpetuation of life
Nuffield Biology: Keys to small organisms in soil, litter, and water troughs

Film Loops.

Year I

Development of the Locust: (1) Pairing and Egg laying.
Development of the Locust: (2) Hatching and Growth
Reproduction in **Hydra**
Rabbit Egg: Fertilization and segmentation
Animal Eggs and Sperms
Fertilization in the Marine Worm **Pomatoceros triqueter.**

Year II

The Control of Bacteria in Food
Predator/Prey Relationships in a Pond
The Growth of Roots

Year III

The Problem of Feeding: (1) Chewing in Carnivores
The Problem of Feeding: (2) Chewing in Herbivores
The Problem of Feeding: (3) The Locust as a Biting Insect
The Problem of Feeding: (4) The Housefly as a Sucking Insect
Carbon Dioxide exchange in **Chlorella** using $^{14}CO_2$
Biological Control: (1) **Apanteles** as a Parasite
Biological Control: (2) Whitefly and **Encarsia**
Malaria: The Dispersal of an Internal Parasite
Seed Dispersal

Year IV

Capillary Circulation of Blood
Camp Followers of Man: (1) Neutral and Beneficial Organisms
Camp Followers of Man: (2) Harmful Organisms
Camp Followers of Man: (3) Wood Boring Organisms
Camp Followers of Man: (4) Garden Organisms
The Conservation of Top Soil Phagocytosis

Year V

Selection by Predation
Meiosis
Microtechniques: (1) Dilution Plating
Microtechniques: (2) Inoculation with a Loop
Removing and Exchanging Nuclei in **Amoeba**
Squash Preparation (of grasshopper testes)
Mating Behaviour of **Drosophila**
Pollination by Wind
Pollination by Insects
Mitosis

2 in. X 2 in. Slides.

Set of 8 slides on Locust Development
Set of 12 slides on **Pleurococcus**
Color transparency comparing chlorophyll absorption spectrum with spectrum of white light.

Photographs.

Mitosis—14 photographs
Meiosis—11 photographs

Record (45 rpm).

The African Clawed Toad, **Xenopus laevis**: Sounds Made During Mating.

NUFFIELD O LEVEL CHEMISTRY

The following materials for this project are published jointly by Longmans and Penguin, from 1966.

Nuffield Chemistry: Introduction and Guide
Nuffield Chemistry: The sample scheme stages I and II: The Basic Course
Nuffield Chemistry: The sample scheme stage III: A Course of Options
Nuffield Chemistry: Collected Experiments
Nuffield Chemistry: Handbook for Teachers
Nuffield Chemistry: Laboratory Investigations Stage IA
Nuffield Chemistry: Laboratory Investigations Stage IB
Nuffield Chemistry: Laboratory Investigations Stage II
Nuffield Chemistry: Laboratory Investigations Stage III—Options.
Nuffield Chemistry: Book of Data.

Background Books.

These supplemental materials are published by Longmans, various dates.
Atoms into Ions
Burning
Catalysis
The Chemical Elements
Chemical Engineering
Chemicals and Where They Come From
Chemicals from Nature
Chemistry and Electricity
Coal
Colloids
Colour
Corrosion

ERIC

Dalton and the Atomic Theory
Detergents
The Discovery of Inert Gases
The Discovery of the Electric Current
Dissolving
Drugs
Fertilizers and Farm Chemicals
Growing Crystals
Humphrey Davey
Inside the Atom
Making Diamonds
Man-made Fibers
Metals and Alloys
Michael Faraday
The Nitrogen Problem
Pasteur
Periodicity and Atomic Structure
The Periodic Table
Petroleum
Pictures in Silver
Plastics
Radioactive Chemicals
The Start of X-Ray Analysis
The Structure of Substances
Sulphuric Acid
Water
Way of Discovery
What is an Acid?

Film Loops and Other Aids.

These titles are published by Longmans and Penguin, various dates.
The first digit of the reference number for each film loop indicates the stage of the O level course for which they were intended. (see Chapter 8 for a discription of the stages.)

1-1 Salt Production.
1-2 Chlorophyll Extraction.
1-3 Whisky Distillation.
1-4 Oil Prospecting.
1-5 Petroleum Fractionation.
1-6 Liquid Air Fractionation.
1-7 Gold Mining.
1-8 Iron Extraction.
1-9 Copper Refining.
1-10 Limestone.
1-11 Fluorine Manufacture.
1-12 Uses of Fluorine Compounds.
1-13 Chlorine Manufacture.
1-14 Chlorine—Uses.
1-15 Bromine Manufacture.
1-16 Bromine—Uses.
1-17 Iodine Manufacture.
1-18 Iodine Uses.
2-1 Measuring the Very Small.
2-2 Gram-Atoms.

2-3 Sulphur Crystals.
2-4 Heating Water.
2-5 Liquid/Gas Equilibrium.
2-6 Solid/Liquid Equilibrium.
2-7 Movement of Molecules.
2-8 Electrolysis of Lead Bromide.
2-9 Cracking Hydrocarbons.
2-10 Plastics.
2-11 Ammonia Manufacture.
2-12 Ammonia—Uses.
2-13 Catalysis in Industry.
2-14 Energy Changes in HCE Formation.
2-15 Radioactive Materials—Uses.
3-1 Growth of Crystals.
3-2 Metallurgical Techniques.
3-3 Metals—Mechanical Properties.
3-4 Giant Molecules—Proteins.
3-5 Using the Pipette.

Diffraction Grids.

(Thirty six grids providing an optical analogy to X-ray diffraction in elucidating crystal structure.)

Periodic Table Leaflets.

Charts.

To accompany film loops 1-6, 2-1, and 2-11.

NUFFIELD O LEVEL PHYSICS

All materials for this project are published jointly by the Longman Group and Penguin Books for the Nuffield Foundation, from 1966.

Nuffield Physics: Teachers' Guide I
Nuffield Physics: Teachers' Guide II
Nuffield Physics: Teachers' Guide III
Nuffield Physics: Teachers' Guide IV
Nuffield Physics: Teachers' Guide V
Nuffield Physics: Tests and Examinations
Nuffield Physics: Guide to Apparatus
Nuffield Physics: Questions Book I
Nuffield Physics: Questions Book II
Nuffield Physics: Questions Book III
Nuffield Physics: Questions Book IV
Nuffield Physics: Questions Book V
Nuffield Physics: Guide to Experiments I
Nuffield Physics: Guide to Experiments II
Nuffield Physics: Guide to Experiments III
Nuffield Physics: Guide to Experiments IV
Nuffield Physics: Guide to Experiments V
Nuffield Physics: Optical Instruments and Ray Diagrams for use with Year III.

NUFFIELD A LEVEL BIOLOGICAL SCIENCE

All products of this project are published by Penguin Education, from 1970, and have the preliminary title *Nuffield Advanced Biology*.

Laboratory Guides.

Control and Coordination in Organisms.
The Developing Organism.
Maintenance of the Organism.
Organisms and Populations.

Study Guide.

Evidence and Deduction in Biological Science.

Topic Reviews.

The Artificial Kidney.
Biological Barriers.
Circulation.
Control of Breathing.
From Egg to Adult.
The Heart-Lung Machine.
Human Pregnancy and Birth.
Interactions.
Metabolism
Photosynthesis.
Thinking Quantitatively I.
Thinking Quantitatively II.
Key to Pond Organisms.

Teachers' Books.

Laboratory Book.
Projects in Biological Science.
Teachers' Guide I.
Teachers' Guide II.
Teachers' Guide to the Study Guide.

Film Loops.

Frog Sciatic Nerve
Handling Radioisotopes I: Carbon 14.
Handling Radioisotopes II: Phosphorus 32.
Locust Ventral Nerve Cord.
Operant Conditioning.
The Use of the Microscope.

NUFFIELD A LEVEL CHEMISTRY

All products of this project are published by Penguin Education, 1970, and have the preliminary title *Nuffield Advanced Chemistry*.

Students Book I: Topics 1-12.

Students Book II: Topics 13-19.

Book of Data: For use with all Nuffield Advanced Chemistry, Physics and Physical Science.

The Chemist in Action.

Teachers' Guide I: Topics 1-12.
Teachers' Guide II: Topics 13-19 and appendices.
Teachers' Guide to the Special Studies.
Examinations and Assessment.

Special Studies.
Biochemistry.
Chemical Engineering.
Food Science.
Ion Exchange.
Metallurgy.

Experiment Sheets, Boxes 1-6.

Programmed Texts.
*Amount of Substance.
Ethanol and Other Alcohols.
Names and Formulae of Carbon Compounds.
*Oxidation Numbers.

Visual Aids.
Overhead Projection Originals.

Film Loops.
Addition to Carbon—Carbon Double Bonds.
Applications of the Mass Spectrometer.
Applications of Paper Chromatography.
The Born-Harber Cycle.
The Hydrolysis Bromoalkanes.
The Manufacture of Plastic Articles.
Organic Analysis by the Mass Spectrometer.
Problems in the Use of Detergents.
Rate of Reaction.
Testing of Plastic Film.
Two-Way Paper Chromatography.

* Forthcoming title.

NUFFIELD A LEVEL PHYSICS

All materials for this project are published by Penguin Education, 1971, and have the preliminary title *Nuffield Advanced Physics.*

Students' Book Unit 1: Materials and Structure.
Students' Book Unit 2: Electricity, Electrons, and Energy Levels.
Students' Book Unit 3: Field and Potential.
Students' Book Unit 4: Waves and Oscillations.
Students' Book Unit 5: Atomic Structure.
Students' Book Unit 6: Electronics and Reactive Circuits.
Students' Book Unit 7: Magnetic Fields.
Students' Book Unit 8: Electromagnetic Waves.
*Students' Laboratory Book.
*Physics and the Engineer.

***Molecules and Motion.**

Teachers' Handbook.

Teachers' Guides: Units 1-8 (For unit titles, see above)

***Apparatus Construction Drawings.**

***Teachers' Guide: Supplementary Mathematics.**

Unit 9: Change and Chance. (For both Student and Teacher).

Unit 10: Waves, Particles, and Atoms. (For both Student and Teacher).

* Forthcoming title.

Film Loops.

Backwards or Forwards? 1.
Backwards or Forwards? 2.
Backwards or Forwards? 3.
Solving a Standing Wave Equation for a Hydrogen Atom.
Wind-Induced Oscillations.
X-Ray Diffraction, 1: Production of the X-Ray Beam
X-Ray Diffraction, 2: Diffraction of Monochromatic X-Rays by a Single Crystal.
X-Ray Diffraction, 3: Diffraction of Monochromatic X-Rays by a Powder Sample.
X-Ray Diffraction, 4: Determination of the Wavelength of X-Rays Using a Diffraction Grating.

16 mm Film.

Change and Chance: A Model of Thermal Equilibrium in a Solid.

35 mm Film Strips.

Unit 1: Materials and Structure
Unit 4: Waves and Oscillations
Unit 9: Change and Chance.

NUFFIELD A LEVEL PHYSICAL SCIENCE

All materials for this project are published by Penguin Education (1972).

Physical Science: Introduction and Guide.

Physical Science: Teachers' Guide I.

Physical Science: Teachers' Guide II.

Physical Science: Students' Workbook.

Physical Science: Students' Sourcebook.

Physical Science: Experimental Instructions.

SCIENCE 5/13

All materials from this project are published by Macdonald Education (1971).

With Objectives in Mind

Working with Wood

Working with Wood: Background Book.

Time

Early Experiences
Science from Toys
Structures and Forces. Stages 1 and 2.
*Metals
*Trees
*Coloured Things
*Change: Stages 1 and 2.
*Change: Stage 3.
*Minibeasts
*Structures and Forces: Stage 3.
*Holes, Gaps, and Cavities.
*Like and Unlike
*Metals: Background Book.
*Using the Environment.
* Forthcoming or in preparation.

NUFFIELD JUNIOR SCIENCE PROJECT

All materials for this project are published by William Collins.

Nuffield Junior Science: Teachers' Guide I
Nuffield Junior Science: Teachers' Guide II
Nuffield Junior Science: Animals and Plants
Nuffield Junior Science: Apparatus

Booklets for Teachers.

Autumn into Winter
Mammals in Classrooms
Science and History

SCOTTISH SCIENCE

There are no texts published by the groups which designed the new Scottish Syllabuses. Details of the syllabuses for Biology, Chemistry and Physics to H grade can be found in:

Biology, Ordinary and Higher Grades: Syllabuses and Specimen Question Papers. Edinburgh: Scottish Certificate of Education Examination Board, 1968.

Chemistry, Ordinary and Higher Grades: Syllabuses and Notes. Edinburgh: Scottish Certificate of Education Examination Board, 1969.

Physics, Ordinary and Higher Grades: Syllabuses and Notes. Edinburgh; Scottish Certificate of Education Examination Board, 1969.

The syllabuses for the Chemistry and Physics courses for the Certificate of Sixth Year Studies may be found in **Certificate of Sixth Year Studies**, Edinburgh: Scottish Certificate of Education Examination Board, 1969.

The Scottish Education Department publishes circulars, newsletters and memoranda for teachers. Two examples of these titles follow:

Certificate of Sixth Year Studies: Notes on Practical Work in Chemistry—Memorandum for the Guidance of Teachers Planning This New Course.

Edinburgh: Scottish Education Department, n.d.

Science Newsletter No. 9: Chemistry Projects. Edinburgh: Scottish Education Department. 1969.

PROJECT TECHNOLOGY

Teachers' Guides.

- **Simple Bridge Structures**
- **Introducing Fluidics**
- **Simple Materials Testing Equipment**
- **Bernouilli's Principle and the Carburetter**
- **Engine Test Beds**
- ***The Ship and Her Environment**
- ***Computer and Control Logic**
- ***Simple Fluid Flow**
- ***Industrial Archaeology for Schools**
- ***Food Science and Technology**
- ***Home and Technology**
- ***Design With Plastics**
- ***Electrical and Electronic Construction Techniques**

* Forthcoming title, planned for publication early in 1973.

All the teachers' guides are to be published by Heinemann Educational Books.

Occasional Papers.

- **School Science and Technology, 1: Applications of Science**
- **School Science and Technology, 2: Science Fairs**
- **School Technology,** Vol. 1. Edited reprints from 1968 issues of the "Bulletin."
- **School Technology,** Vol. 2. Edited reprints from the 1969 issues of the "Bulletin."

The occasional papers are distributed by English Universities Press.

Details of impending publications may be found in **Schools Council Project Technology: The Next Two Years.** Loughborough College of Education: Project Technology, 1970. (Available from the Schools Council.)

BIOLOGY FOR THE INDIVIDUAL

All books from this project are published by Heinemann Educational Books. There is a teachers' and pupils' edition of each title.

Biology for the Individual, Book 1: **Sorting Animals and Plants into Groups.**
Biology for the Individual, Book 2: **How Life Begins.**
Biology for the Individual, Book 3: **Movement in Animals.**
Biology for the Individual, Book 4: **Support in Animals and Plants.**
Biology for the Individual, Book 5: **The Problems of Life in Hot, and Cold Climates.**
Biology for the Individual, Book 6: **Microbiology 1.**
Biology for the Individual, Book 7: **Microbiology 2.**
Biology for the Individual, Book 8: **Plant Reproduction.**

Publishers' Addresses

COLLINS

William Collins and Sons
14 St. Jame's Place
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England

ENGLISH UNIVERSITIES PRESS

St. Paul's House
Warwick Lane
London
England

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48 Charles Street
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Holborn Viaduct
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LONGMANS

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4 Little Essex Street
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PENGUIN

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