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ABSTRACT

This guide for pilot study groups deals with curriculum planning, the writing of materials, and evaluation methods. Included are principles to be followed in the construction of a biology syllabus for age groups 11-17, a scheme for unified science for pupils aged 11-13, criteria for selection of course content, and an example outline of content for a secondary school biology program. Guidelines are given for the writing of teacher's guides, for the selection of laboratory and field equipment, and for out-of-school activities for pupils. The general evaluation scheme includes assessment of teaching strategies and student interests. Recommendations are given for constructing achievement tests and for stating objectives. A list of objectives for science education in secondary schools is included as an appendix. (EB)

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United Nations Educational
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UNESCO PILOT PROJECT ON NEW APPROACHES AND TECHNIQUES IN BIOLOGY TEACHING IN AFRICA

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A GUIDE FOR PILOT PROJECT STUDY GROUPS

by

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CONTENTS

SECTION 1. Terms of Reference for the Preparation of a Study Guide

1.1 Write a Guide of a maximum of 40 standard pages for the national study groups established in Africa within the Unesco Biology Teaching Pilot Project. The Guide will cover the following subjects:

a) evaluation of the effectiveness of the material produced by the International Working Group (Cape Coast, 1967/1968) of the Unesco Biology Teaching Pilot Project;

b) principles to be followed in the construction of a Biology Syllabus for age group 11-17, and the place of biology in an integrated science teaching curriculum for age group 11-13;

c) criteria for deleting or reducing topics generally taught in conventional biology teaching programmes, for introducing essential concepts and matters of practical interest such as : "Man's Inheritance", "Man and his Environment", "Interdependence of the Living and Non-Living", "The Biology of an Agricultural Field", "The Management and Conservation of Man's Biological Resources", "Recommendations of Criteria to be used for the Choice of Laboratory and Field Equipment for Biology Teaching Stressing Essential Modern Concepts", "Suggested list of minimum Equipment for a Class of 25 Pupils, Covering all Secondary School Biology (Age Group 11-17)", "How to Plan and Write a Curriculum and Teachers' Guides", "Construction of Achievement Tests and Statement of Objectives for Classroom Trial and Assessment of an Experimental Biology Teaching Programme", "An Example of Outline of Content of a Modern Secondary School (Age Group 11-17) Biology Teaching Programme", "Outline of Out-of-School Activities for Pupils".

SECTION 2. Interpretation of Terms of Reference

2.1 Certain materials produced by the Unesco Biology Teaching Project for Africa were available to the author at the time of preparing this Guide. These were Parts 1 to 7 of the texts (experimental editions) and the Teachers' Guides to fifteen loop films. The Final Report by Dr. Andrzej Grebecki and Dr. Leonard Brian of the International Working Group (English Speaking African Countries) September 1967-July 1968 (Reference SC/MD/6) was also available. These materials were carefully considered in preparing this Study Guide.

2.2 The concept that each country would develop its own syllabus and curriculum was the main guiding principle. It was recognised, however, that many member countries may choose the materials of the Unesco Biology Teaching Project for Africa as resources for their locally developed curricula.

2.3 It is recognised that each country has individual requirements, resources and objectives. The recommendations and criteria presented in this Guide are included not as firm policies but in the hope that they may assist each Study Group develop its own plans and systems for the implementation of new courses in biology.

SECTION 3. Evaluation of the Effectiveness of the Material Produced by the International Working Group (Cape Coast, 1967/1968) of the Unesco Biology Teaching Project

The Need for Evaluation

3.1 The effectiveness of experimental editions of educational materials must be carefully evaluated in schools. This is particularly important when the materials are produced by a central agency for adaptation by diverse international school systems.

3.2 Evaluation is necessary for the following reasons.

i. To determine whether the objectives of the authors match objectives of relevance and importance to the school system concerned.

ii. To check whether it is possible to attain under local conditions, all the stated and implied objectives of the authors.

iii. To determine whether the concepts developed in the course are relevant to local needs.

iv. To check whether the factual information is relevant and understandable in the region concerned.

v. To discover if individual concepts and the conceptual development of the programmes are suitable for the various age levels and abilities of local pupils.

vi. To discover the interest and attitudes developed by the pupils in the new materials.

vii. To check whether the practical activities are feasible for children and schools for whom they are intended.

viii. To investigate practical problems of using the materials, e.g. the availability of practical facilities required; the time needed for each part or topic, and administrative problems.

ix. To check if the literary style, presentation of illustrations and the nature of questions are suitable for local children.

x. To diagnose the special problems of teachers in order to prepare an effective curriculum for pre-service or in-service training of teachers.

3.3 Information from the evaluation of the materials provides detailed feed-back. It would allow each national study group to effectively adapt materials for its local school system.

Selection of Schools for Evaluation

3.4 While it is true that the larger the number of schools and pupils evaluated the more reliable the evidence, large numbers can be an embarrassment. A great mass of information comes from evaluation studies and unless there are computers or big clerical resources, data from large samples may be unmanageable. Evaluation studies must be realistic. Adequate evidence can be obtained for major decisions from as few as nine schools, with one class from each grade in each school, provided they are representative of the school system as a whole.

3.5 If only nine schools are chosen they should be selected after a careful survey of at least twenty schools regarded as fairly representative. Possibly the sample of nine could consist of three groups of three as follows:

Group I : Three schools with classes rated as having a relatively high chance of using the materials successfully.

Group II : Three schools with classes rated as having only average chance of successfully utilising the new materials.

Group III : Three schools with classes rated as possibly having a below average chance of success with the new materials.

3.6 Selection of the nine schools should be made by a group nominated by the evaluators. These people should visit each class in pairs and use a rating scale to give each a score reflecting its potential. An example of a form that could be used to collect this information is given on pages 5 and 6.

(FRONT)

Selection of Classes for Evaluation Study

A. Name of School ---------------------------- Telephone ------

B. Name of Principal --------------------------------

C. Grade (Form or Class) Identification ----------------------

D. Name of Biology Teacher ------------------------------------

E. Month and Year Materials First Used -------------------------

F. Language of Instruction (where relevant) --------------------

G. Category of School (Public/Private/Subsidised etc.) ----------

Quality to be Rated	RATING (3, 2 or 1) See Instructions on Back
1. Qualifications of the teacher	
2. Study room facilities	
3. Equipment	
4. Periods available	
5. Time available for lesson preparation	
6. Results of examinations in all subjects at the end of the previous year	
7. Results of the last monthly or terminal test in Biology	
8. Effectiveness of the classroom teaching in Biology	
9. Amount of material covered	
10. Interest of pupils in the new materials	
Total Rating =	/30

Instructions for Rating

1. Qualifications of the teacher
   3 = M.Sc., B.Sc., B.T.
   2 = B.Sc., B.A. with maths and F.Sc.
   1 = Matric with Science or F.Sc. or B.A. only without Science.
   Note : Mark 3 drops to mark 2 or 2 to 1 if the teaching is by a teacher in a subject other than the major subject of his degree.
2. Study room facilities
   3 = Study room equipped with approved tables and chairs, blackboard, scale, cupboards for keeping equipment.
   2 = Study room, but equipped not like the above.
   1 = No proper study room.
3. Equipment
   3 = Equipment available as recommended.
   2 = Equipment is taken from Higher Secondary Laboratories whenever required.
   1 = Equipment is not always available from any source.
4. Periods available
   3 = Double period and single periods available, and normal load on teacher.
   2 = Single periods only, with heavy load on teacher.
   1 = Less periods, and heavy load on teacher and teacher not teaching his major subject.
5. Time available for preparation
   3 = Teacher has sufficient opportunity to prepare and organise his materials before each lesson.
   2 = No formal opportunity is provided but teacher manages through student or other methods to organise materials.
   1 = In most cases unable to organise materials for lesson.
6. Result of the examination of the previous class
   3 = If 60% of the students obtained 60% or higher marks and most of others between 45% to 59%.
   2 = If majority of the students obtained between 45% to 59% and others less than 45%.
   1 = If m ajority of students obtained less than 45% marks.
7. Results of the last monthly and terminal test in Biology
   Rate as above in No. 6.
8. Effectiveness of the classroom teaching in the subject
   3 = Teacher closely follows the instructions given in teachers' guide.
   2 = Teacher follows partly but not consistently, instructions in teachers' guide.
   1 = Teacher very rarely makes use of instructions in teachers' guide.
9. Amount of material covered
   3 = Over 80% of all topics have been covered, according to number of periods allocated in teachers' guide/syllabus.
   2 = Only 50% to 80% of the topics have been covered.
   1 = If less than 50% of the topics have been covered as above.
10. Interest displayed by students in the new course (evidence from extra curricula activities, classroom observation, talks with pupils)
    3 = Good reaction in classroom teaching and interest shown in performing the experiments in class and outside.
    2 = Reaction to the teaching in class is average and interest average, in class and outside.
    1 = Reaction to the teaching in class and outside below average, little or no involvement in extra curricula activities such as Science Clubs.

Of course many of the decisions in such a procedure are subjective but can be arrived at reasonably fairly after discussion between observers, discussions with pupils and teachers, observation of lessons and facilities and examination of student records. The method ensures systematic observation and reduces bias in selection. The schools can be ranked by their scores out of thirty and after discussion, suitable high, mid and low scorers selected. It may be that the sample of nine schools for Grade (age) I is different from the nine for Grade (age) II and so on. But nine representative classes should be chosen for each grade in the school system.

Evaluation Procedure

3.7 For each class the evaluators should collect and analyse data from the following sources; visiting each class about once a month.

i. structured interview with teacher

ii. interviews with selected pupils

iii. test results from pupils

iv. written statements from pupils

v. observations of classroom practice

3.8 The type of information collected could be as follows:

i. results of pupils objective tests of achievement in knowledge and understanding of the work set for the month

ii. statement by the pupils on their interests and attitudes (essay or interview)

iii. opinions by the teacher on the following -

a. scope and relevance of the objectives of the materials

b. specific difficulties in text and practical work

c. estimates of amount of work covered, and of difficulty and interest of the topics of the month.

iv. independent ratings by the teacher and by the observer of achievement of selected objectives in the teaching of the current topic. The following list suggests some objectives that might be considered in this way.

Objective	Rating of Degree of Achievement by Class as a Whole (5 = high 1 = low)	
	By Observer	By Teacher
I. Knowledge and Understanding 1. Knowledge of facts in text 2. Understanding of facts in text 3. Response to questions 4. Knowledge of facts of experiment 5. Understanding of principle of experiment 6. Understanding conclusions from the experiment 7. Ability to reach independent conclusions		
Total		
II. Emotional Reaction 8. Interest during introduction to lesson 9. Interest during the main part of lesson 10. Interest during conclusion of the lesson 11. Interest in demonstration experiments 12. Interest in experiments performed by pupils 13. General attitude to biology lessons 14. General scientific attitude		
Total		
III. Practical Skills 15. Making biological drawings 16. Handling glassware 17. Handling dissection instruments 18. Handling biological specimens 19. Handling measuring instruments 20. Using a lens 21. Using a microscope		
Total		
Grand Total =		
Average of both teacher and observer		

v. the classroom teacher should be asked to mark on a percentage rating scale his estimate of degree of success in teaching by the recommended and preferred methods. These estimates should then be verified by an observer watching typical lessons. The types of methods used could be as follows :

verification (0) to problem solving (100)

teacher active (0) to pupil active (100)

use of blackboard (0) to use of objects and specimens (100)

use of demonstrations by teacher (0) to experimentation by pupils (100)

Estimates of use of desirable teaching methods could be recorded as ratios, as in the following example

Teaching Method (shown as ratios of desirable to undesirable)	Percentage Use of Desirable Method by Teacher		
	Estimated by Teacher	Estimated by Observer	Average
1. Problem solving / Verification	55	55	55
2. Pupil active / Teacher active	30	35	33
3. Use of objects and materials / Use of blackboard	50	40	45
4. Pupils do experiments / Demonstration experiments	30	60	45

vi. all the above information should be assessed at the conclusion of the year for the course as a whole. Also at that time pupils should be given a list of all topics covered in the year and asked to vote (5, 4, 3, 2 or 1 perhaps) on level of difficulty and degree of interest for each topic.

Processing of results and use made of the information

3.9 There should be a central office for co-ordination of information obtained. This should have a full-time staff of one or two educators with clerical assistance.

3.10 Quantitative data should be grouped and totals or averages obtained separately for each school group of three schools in the sample, and for the total sample. Qualitative information should be read and analysed into categories, indicating frequency of mention of each category.

3.11 The information relevant to each topic should be examined critically but very impressionistically. The data should provide, for each topic, and for the course as a whole, impressions of the effectiveness of the materials in schools with high, average and low degrees of predicted success. This should give a clear indication of how the materials would need to be adapted or modified for local school systems. The data should be used as a basis for changing the objectives, content, sequence, emphasis, methods, or examples, in ways likely to overcome obvious weaknesses, and fit the materials more closely to local needs.

SECTION 4. Principles to be Followed in the Construction of a Biology Syllabus for Age Groups 11-17

4.1 The evaluation of materials produced by the International Working Group having led to their adaptation for local needs, the next step is to develop a syllabus or course of studies. The adapted materials could be used as curriculum resources for the new syllabus.

Step I. Purposes and Limitations

4.2 The first step in constructing a syllabus is to carefully decide the purposes and parameters of the course. That is, for whom it is intended, its place in the curriculum, and the practical restraints on its design and implementation. Key decisions include the following.

i. Will the course be compulsory or optional? If optional will it be designed for boys and girls; below average, average or above average abilities; city or rural children, etc?

ii. Is the main purpose of the course to prepare for a later stage in education in biology or is its main purpose to contribute to the general education of pupils? Is this purpose different for say ages 11 to 13; 14 to 15; and 16 to 17?

iii. Does the school system have a large 'drop-out' rate each year? Is there a good or poor 'holding power' in schools after the age of compulsory attendance at school? Clearly if the later years of schooling become more and more selective the nature of the course must change from age level to age level.

iv. Is the population for whom the course is intended widely diverse or fairly homogeneous in language, geographic location, cultural background, vocation and socio-economic rating? If diverse, the course must cater for the differences between children.

v. Is the medium of instruction to be mother tongue or some other language? This will, for example, enormously influence the quantity of material to be included.

vi. What are the minimum resources in the schools for the implementation of the new course? Do some schools teach biology in ordinary classrooms or do all schools have laboratories? Can all schools obtain basic apparatus? Will the syllabus assume or not assume that all school rooms have access to water and electricity?

vii. Will biology be taught as a separate subject, as part of a multi-stranded programme of correlated science or as part of an integrated unified science course? If the latter, will the biology provide main or subsidiary themes for integration?

viii. What other subjects can be assumed to be taught concurrently? Mathematics? Physics and/or Chemistry? etc. Will the syllabus assume an understanding of these other subjects? Will it actually use units from these other courses?

ix. Will texts, teachers' manuals, visual aids and similar resources be available to implement the course?

x. What is the background of the average teacher? Will it be necessary to undertake massive programmes of re-training, or just re-orientation conferences for qualified teachers?

xi. What opportunities are there for visits to farms, natural history reserves, museums, zoos, industry, ecological environments? What types of environments are most wide-spread? Will it be necessary to provide alternative units for various regions?

xii. What are the common animals and plants available to the teacher? Is there information on their biology? If not, do the syllabus makers envisage that this information will be made available?

Step II. Determining Objectives

4.3 The second step in constructing the syllabus is to carefully determine the over-all objectives of the programme. There are many published statements of objectives for science in schools. A most comprehensive taxonomy, currently (July 1969) being considered by the N.S.W. Syllabus Committee in Higher Secondary School Science (Australia), has been included as an Appendix to this report. This and many similar statements have been influenced by B.S. Bloom's well known Taxonomy of Educational Objectives. Such a statement is a useful start for any syllabus committee in science. They should modify this according to their special needs. The following criteria may be useful in making such modifications.

i. The spectrum of objectives should be broad. Many world famous syllabuses confuse teaching strategies with objectives and so place a great deal of emphasis on developing in a child an "enquiring scientific mind" at the expense of other equally important objectives. The statement of objectives, then, can be too narrow. Objectives should stress emotional factors (interests and attitudes), and practical skills as well as knowledge and understanding.

ii. Certain groups of objectives will be more relevant to biology than to say physics and chemistry and so should be given more emphasis.

iii. Care should be taken to review world trends in emphasising certain objectives. These trends include -

a. The development of awareness in recent concepts in science at the frontier of man's knowledge.

b. An emphasis on processes and methods of science.

c. An explanation of the power of science in solving personal, community, national and international problems. An emphasis on the relevance of science in everyday life - for biology there is a special role in helping mankind understand and control disease, and solve problems of population, food, and of conservation of resources.

d. An emphasis on the uncertainty and tentativeness of science, on the nature of hypothesis, on the many examples of lines of enquiry that lead to false hypotheses, and on the constant review and revision of scientific ideas in the light of new evidence.

e. A development of an understanding of scientists as people with real human problems, difficulties, joys and successes. One of the faults of much earlier science teaching is that it has been impersonal or dehumanised.

f. A reduction in detailed factual knowledge and an emphasis on broad principles and concepts.

g. A stress on the development of practical skills.

h. A desire to build positive attitudes towards science, to develop scientific attitudes to life and to foster a deep lasting interest in science.

iv. It may be that certain objectives for older pupils say, 14 to 16, are different from those for pupils 11 to 13. Objectives for senior pupils may reflect the influence of selection, vocational needs, preparation for tertiary studies, a greater level of maturity of the pupils, and an improvement in school facilities or in the qualifications of teachers of senior classes.

Step III. Determining Structure and Sequence

4.4 After determining the objectives, the syllabus makers should decide on the most suitable arrangement of material for achieving these over-all objectives. Three possible models are presented for consideration.

4.5 Firstly there is a non-sequenced or unstructured approach. A series of topics or units are developed and may be taught in any sequence according to the requirements and interests of individual teachers.

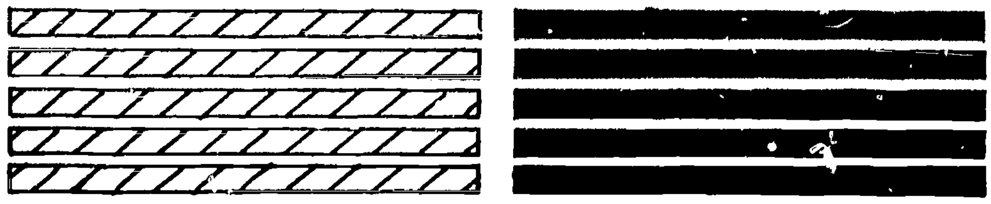
4.6 Secondly there could be a linear development of concepts. In this scheme, each topic would be discussed only once. For example, for age 11 plant biology; age 12 animal biology; age 13 human biology; age 14 biology of cells, and so on. There are of course grave dangers in a strictly linear sequence. It could not achieve all its objectives until the conclusion of the total programme. There is a danger that a pupil in say junior high school may not appreciate why it is necessary to study certain topics. There is some possibility that parts of the programme could appear unreal, unrelated to the needs of the pupil and generally academic in orientation. To overcome this problem, care must be taken to provide an occasional section which draws together principles and generalisations. This is particularly necessary at critical points of 'drop-out', such as at the end of lower school or at the school leaving age. There should be, at such points, sections drawing together the main ideas of the syllabus and consolidating objectives.

4.7 In a linear programme of biology there could be a somewhat abrupt transition from the work of middle school to the work of say A-level unless special care is taken to avoid this. Of necessity the work in lower and middle school is based on simple observation and experimentation. While this should continue at A-level, the work at the same time generally requires a much more sophisticated way of thinking. It could emphasise generalisations, abstractions, concepts and theoretical models. Care should be taken, therefore, to reduce the abruptness of the change by providing 'bridges' or 'natural links' between the junior or senior courses. Articulation can be of two types as shown by the following diagram. (Page 15). In the diagrams each line represents the linear development of a central theme of biology. Bars shown represent essentially concrete experiences of observation and experiment, and bars shown represent experiences depending largely on abstractions, generalisations and conceptual thinking.

The type of articulation shown in A should be avoided and that shown in B should be developed as far as possible.

Middle School A-Level

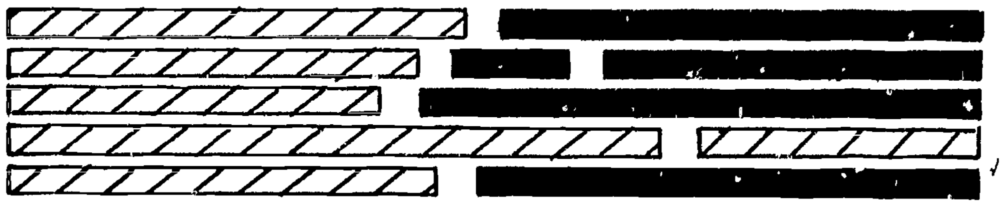
A



Abrupt Transition

Middle School A-Level

B



Some Links and Bridges Between Middle School and A-Level

4.8 There is a strong argument in favour of linear structure, but this is based on economic rather than educational criteria. An accepted view is that school courses in many developing countries, largely for economic reasons, must be compressed into as short a span as possible, while at the same time ultimately reaching standards comparable to those in say Britain, Australia, U.S.S.R. or U.S.A. Repetition of material must, therefore, be cut to a minimum. The spiral or concentric approach usually adopted in the teaching of science in some school systems is a luxury that many countries cannot afford.

4.9 The third approach is to develop each major concept spirally or concentrically. For example, the concept of photosynthesis could be introduced in a simple way for age 11, discussed chemically at age 12, developed through more advanced experimental work at ages 13 and 14 and treated at the molecular level in cell biology for older pupils.

4.10 The concentric method has the advantages of providing reinforcement in learning, and it allows deeper and deeper analysis of concepts. It has the added advantage of allowing the syllabus writer to give a balanced treatment of topics at various ages so that the incomplete education of an early-leaver is at least a balanced education. The difficulty for developing countries is that a fully c ncentric programme takes much longer than a strictly linear sequence, is consequently more expensive, and requires parents to keep children at school longer to cover the same material of a parallel linear programme.

4.11 Probably the best approach for most African countries would be to develop an essentially linear frame-work but to build-in certain concentric themes such as the cell; the concepts of evolution and adaptation and the principle of interdependence.

Step IV. Determining Teaching Strategy

4.12 The next step is to determine the most effective means of teaching within specified limitations and structure of the syllabus, to attain stated objectives.

4.13 Should it have been agreed that objectives should reflect the trends listed in 4.3 (iii), then certain methods of teaching should be encouraged and provided for in the syllabus. The syllabus workers might then formulate strategies such as follows:

i. Wherever appropriate, an enquiry or problem solving approach should be used.

ii. A quantitative approach should be used wherever appropriate.

iii. There should be an emphasis on observation and experiment.

iv. Field excursions and out-of-doors activities should be developed wherever possible.

v. Discussion and analysis of data should be encouraged.

vi. There should be considerable use made of locally available plants and animals.

vii. Visits to farms, hospitals, museums, zoos, natural history reserves, industrial sites and ecological environments should be encouraged.

viii. From time to time pupils should try to solve open-ended problems provided they have adequate resources for the solution of these problems.

ix. Use and appreciation of the body of knowledge contained in a range of reference books and magazines, should be a central activity.

x. The teacher should, wherever possible, assume the role of consultant rather than simply be a source of information.

xi. Wherever possible individual pupils should be encouraged to work through the course at their own pace. Provision should be made for individual differences in ability, interest and aspiration.

xii. An emphasis should be placed on developing an understanding of the pupils' immediate local environment.

4.14 If the selected objectives differed in any significant way from those suggested in 4.3 (iii), the teaching strategies would need to be modified accordingly.

Step V. Selecting and Arranging the Content

4.15 When the rigorous procedures of Steps I to IV are followed with care and precision, syllabus makers are frequently surprised at how quickly and logically the actual subject matter can be selected and arranged.

4.16 Keeping all previous steps in mind, major concepts or themes should be selected and matched carefully against objectives of Step II. Any that do not contribute to achieving these objectives should be rejected. Those surviving should then be checked for feasibility against the criteria of Step I and for compatibility with the preferred strategies of Step IV. Those not matching these criteria should also be rejected.

4.17 As an example of this process suppose the following concepts were proposed for children aged 12 years:

the population ecology of man
the interdependence of living things in a pond
the biochemistry of cellulose in food
radiation and mutation
the orders of the Coleoptera
the shapes of leaves

The last two may well be rejected on the grounds that their limited scope would not achieve a sufficient range of agreed objectives, also because they are not so suitable for our chosen strategies. We may agree that the other four are probably relevant to our objectives. We reject the radiation topic, however, because of lack of resources in the schools and the topic on food is also rejected because it would not be suitable for the pupils we defined in Step I. Only the first two topics would survive.

4.18 Having chosen the major concepts or topics for each age group they should be arranged in linear and/or concentric sequences, and then the *minimum* information needed to develop each concept should be selected.

4.19 The minimum information needed to develop the concept should be written out in the form of objectives, each compatible with and developed from the over-all objectives of the syllabus. Some of the objectives should be expressed in behavioural terms. For example, for the concept of "Interdependence of Living Things in a Pond" the information of the syllabus might be written out as follows:

Unit - Interdependence of Living Things in a Pond

Pupils should know and understand the following:

plants make high energy substances
animals get high energy substances from plants
some animals eat plants, others eat other animals
there are decomposers such as bacteria in a pond community
living things in a community are linked by food chains

The pupils should be able to:

identify aquatic organisms that photosynthesize
collect animals from a pond and identify the herbivores and carnivores
construct some typical food chains of the pond community

At the conclusion of the unit, pupils should demonstrate interest in the topic and show they have an inquiring attitude by voluntarily undertaking activities such as:

collecting, keeping and studying pond organisms in aquaria jars
reading about pond life in books and magazines
discussing the implications of food chains for other organisms such as man

SECTION 5. The Place of Biology in an Integrated Science Teaching Curriculum for Ages 11-13

5.1 There is a world trend towards teaching biology together with physics, chemistry and earth science, to pupils 11 to 13 years of age, in either correlated or integrated syllabuses. This has powerful educational, vocational and administrative advantages, provided such a course has clearly stated objectives, an obvious structure and defined strategies. The danger of the programme consisting of isolated topics with little over-all coherence must be remembered. This was what discredited so many of the so-called "General Science" programmes of the previous three decades. The goal must be to produce a programme of unified science. Many science educators today are convinced that the traditional division of science into chemistry, physics, biology and geology are conventions only, developed by research workers for their convenience. They argue that the child at school does not face the problems of his environment chemically, physically, biologically but totally. The nature of science is interdisciplinary.

5.2 The most successful of the current programmes of unified science fuse together studies of life, matter and energy into a unified set of relationships. They achieve unity in a number of ways. (i) Some have a series of scientific themes such as 'energy' or 'evolution' which, developed concentrically from level to level, brings together all the traditional strands of science. (ii) Others use the processes of science as the key to integration. (iii) A third approach is to use 'levels of organisation' as the main theme - e.g. electrons ➡ atoms ➡ molecules ➡ cells ➡ organisms ➡ populations. (iv) Another method is to develop the course historically, taking relevant case histories from all branches of science, especially case histories of interdisciplinary significance. (v) Another method is to retain the identity of the four main strands of science but choose examples which stress their interdependence and interaction.

5.3 While all these methods have merit and have been successful, most have been used in sophisticated school systems in the United

Kingdom, the United States or in Australia. For countries with developing educational systems, those principles of curriculum construction listed in Section 4, especially relevant to their needs, must be kept in mind. For them the principle of integration should be determined by personal and national needs rather than by the dictates of science as a discipline.

5.4 For most pupils, the most immediately urgent need and interest is to 'know themselves'. Biology, and hence the biology of man, therefore, should be a major theme. In regions with problems of over-population and shortages of resources, this becomes urgent and demanding. It is becoming increasingly apparent that these problems now regional, will all too soon become world problems. In order to give children an awareness of these issues and to better equip them for their solution, the integrating theme for programmes of unified science should be "Man and the Understanding and Control of His Environment".

5.5 The scheme on page 21 presents a conceptual model for a programme of unified science based on the theme suggested.

5.6 A sequence of topics from the conceptual scheme in paragraph 5.5 could be variously programmed according to local requirements. A probable sequence of major topics could be:

i. requirements of life
ii. the human body
iii. man's origin, evolution and place in the universe
iv. man's understanding of his physical environment
v. man's understanding of his fellow man
vi. man's control of environment
vii. man's developing future

5.7 The reality and relevance of such a programme for the life of a child is clear. There are obvious bridges for a transfer of objectives, principles, concepts and emotions, and skills to other areas of the curriculum and to everyday life.

5.8 The materials produced so far by the Unesco Pilot Project for Biology Teaching in Africa are admirably suited for such a programme. They emphasise man and the environment of man, and

A SCHEME FOR UNIFIED SCIENCE FOR PUPILS AGED 11 TO 13 YEARS.

REQUIREMENTS OF LIFE

Chemicals and Raw Materials needed.
Dependence of Animals on Plants.
Photosynthesis.
Light Energy - a basis of all life.
Types of Energy involved in living processes. Heat, Sound, Light, Cosmic radiation, Nuclear radiation, Chemicals, Electricity.
Biological Cycles in Nature. Carbon and Nitrogen Cycles.

Man's Origin, Evolution, and Place in the Universe.

Life.
Its nature and probable origin.
The story of evolution.
The origin of man.
The place of man in an over-all pattern.
Diversity of life and of environments.
Schemes of classification.
The Solar System and Earth.
The Universe.
The qualities of earth which make life possible. Physics, chemistry and geology of the earth.
Is man alone in the universe?
Contact with galactic culture.

THE HUMAN BODY

(applying, where relevant, the principles of chemistry, physics in an explanation of function).

The Structure and Functions of the human body. Study of a co-ordinated aggregate of cells.
Chemical and Physical requirements of cells. Basis for life. How the systems of the body operate in co-ordination.
Self-awareness.
The concept of consciousness and personality.

Man's Understanding of his Physical Environment.

Basic principles and laws of physics, chemistry and geology.
Processes of science.
History of man's scientific exploration of his environment.

Man's Understanding of his Fellow man.

Elementary concepts of sociology and anthropology.
Science and international understanding.
Moral responsibilities leading (if desired) to spiritual considerations.

Man's Control of Environment.

Harnessing and applying various forms of energy.
Invention and application of machines.
Control and use of other living organisms - problems of disease - concept of conservation.
Engineering the environment.

MAN'S DEVELOPING FUTURE

Understanding of self and future control of environment. Accent could be placed on:-

i) Creation of life;
ii) Conquest of disease and premature old age;
iii) Problems of finding enough food for all;
iv) Control of populations;
v) Nuclear energy;
vi) Space travel;
vii) Contact with a galactic civilization that may exist.
viii) ?????

could be used as the integrating core of a unified programme in science.

SECTION 6. Criteria for Deleting or Reducing Topics Generally Taught in Conventional Biology Teaching Programmes for Introducing Essential Concepts and Matters of Practical Interest

6.1 Many established courses of biology, even today, are based on a systematic approach. Such courses may include a basic treatment of the characteristics of living things, of physiology, ecology, evolution, genetics and development. These topics, however, are ancillary to a sequential treatment of the main groups of plants and animals from Thallophytes to Angiosperms and from Protozoa to Chordata. The main rationale for this type of course can be traced back to a need in the late nineteenth century to demonstrate the course of evolution, and to provide convincing proof that evolution had occurred. Such courses are usually concerned with careful studies of the structure of individual organisms, and with full descriptions of life cycles of complex organisms, such as wheat rust, ferns, earthworms or starfish. They generally include full descriptions of the systems of classification and of the characteristics of the various taxonomic groups.

6.2 Two trends in the past decade have made it necessary to re-examine the systematic approach to the biological curriculum. The first is the expansion of knowledge in biology. Biology is now the fastest growing of the traditional sciences. It has been estimated that the issue of *Biological Abstracts* for the year 2000, given present rate of expansion of biological knowledge, will be about 100 feet thick if in the same format as now. There are whole new areas of biology - ultrastructure; energetics; population ecology; population genetics; space biology; molecular biology, and so on. The second is a change in the recognised objectives of science education. Modern courses of biology not only stress acquisition of knowledge and understanding, but also appropriate attitudes and interests and practical skills. *A central* *objective is to put humanity into science teaching* to make it personally and directly meaningful to children. It is no longer thought of merely as an academic exercise or a rigorous discipline in schools only to prepare children for university or college.

6.3 In revising conventional or long-standing biology programmes ruthless cuts must be made to eliminate much traditional material, both to allow room for newer topics and concepts, and to give teachers enough time to use the recommended teaching strategies of paragraph 4.13. Only in this way will the objectives of the courses be achieved.

6.4 The first step in revising an older type syllabus is to *carefully match each of its topics against the new set of objectives.* Anything that does not clearly and unambiguously contribute to these objectives should be eliminated.

6.5 The following criteria may be helpful in reducing the content of a traditional programme.

i. Choose key concepts with broad explanatory power such as 'adaptation'; 'inter-relationship'; 'continuity of life'. Select only enough factual information to establish and consolidate each concept.

ii. Choose topics which relate to the life and environment of the child as closely as possible. In farming communities include topics on agriculture, such as the ecology of a field,or plant and animal breeding; in city communities include topics related to industry and urban life. Try always to include concepts basic to family planning, health, hygiene, social welfare, and conservation of resources. Cater too, for vocational ambitions and preferences. Biology must be a meaningful human experience. It must contribute to the solution of personal, community and national problems and to a child's chosen vocation in life.

iii. When choosing between two closely contending topics or concepts always choose the one that lends itself best to inquiry learning through observation and practical activity on the part of the child. This implies a drastic reduction in purely descriptive biology.

iv. Choose some topics that stress the processes of science, e.g. how scientists have learned about the nature of the gene; about the control of parasitic disease or about the balance of nature in an agricultural community.

v. Choose at least some topics that take pupils to the very frontier of knowledge and which demonstrate the tentativeness and uncertainty of science; but at the same time its progress and its wonder and excitement.

vi. When deciding on what animal to use as the main experimental example, think carefully if it is really necessary to go beyond *man*. (Of course use a locally available mammal - rat or cat or rabbit - for demonstration of anatomy by dissection).

vii. Always emphasise topics and concepts of national and local significance. These may be of significance because of a local research worker, because of local economic factors or because of availability of local resources to teach them effectively. Choose topics, for example, that can be well illustrated by use of local animals and plants.

viii. Interest is an important criterion. Children are rarely interested in details of structure or in the rationale of a classification scheme. They are interested in themselves and their relationships with environment. Children are also more interested in animals than plants so include more about animals than about plants.

ix. Never teach about a structure without its related function and only then if the function contributes to a major concept.

x. Use a new technical word only if it will be needed over and over again and if it is really necessary for simplified explanation. Seek hard for simple every-day words in lieu of technical terms. Do not introduce technical terminology for its own sake.

xi. Choose topics that will encourage pupils and teachers to study out-of-doors. Environment must be experienced at first hand to be understood and valued.

xii. Choose topics that are most likely to capture the excitement, imagination and wonder of children in the hope they will pursue these topics in voluntary reading or discussion. Instead of the structure and life cycle of *Fucus*, discuss the role of algae in life support systems in space travel, in the food cycle of the local fish farm, etc.

xiii. Choose topics to emphasise that scientists are human beings with human emotions and ambitions; human failures and human successes.

xiv. Remove topics that require elaborate instrumentation or sophisticated techniques. These will only introduce frustrations and failures and do not really contribute to accepted modern objectives of school science. Consider carefully, for example, if the microscope, *as such*, is really needed for children aged 11 to 15. Consider carefully if you need precision in say dissection or field survey. Your concern should not be to train biologists in rigorous technique but to develop understanding, general skills and appropriate attitudes in children.

xv. Teach diversity and an explanation of diversity through concepts such as adaptation, genetics, community and population ecology and evolution, but not as taxonomy. Classification should be taught as a process of science, but not as a body of knowledge. Do not introduce schemes of classification or the scientific names of animals and plants for their own sake.

xvi. Finally, choose topics that stress the importance of the scientific attitude in fields other than science. An open mind; suspension of judgment; readiness to recognise the effects of emotions, habits and prejudices on judgments and observations and willingness to give up untenable hypotheses, are all elements of this attitude. Place emphasis, then, on how man is learning to understand and control his environment, because this will encourage the development of these unbiased and objective attitudes.

SECTION 7. Criteria to be Used for the Choice of Laboratory and Field Equipment for a Biology Course Teaching Essential Modern Concepts

7.1 If the teaching strategy advocated is to foster inquiry and problem-solving through activity, then the school must be adequately equipped with apparatus for laboratory work and field teaching.

7.2 To be adequately equipped, however, does not necessarily mean large quantities of expensive or elaborate resources. Even advanced concepts of molecular biology can be adequately demonstrated without highly specialised apparatus.

7.3 Apparatus should not just be selected at random from catalogues or supply lists. There is really no such thing as an agreed stock of apparatus and equipment. The first step is to analyse the content specifications of the syllabus; to consider the objectives of the course and to remember the teaching strategies that have been recommended. For each topic, list the essential equipment needed to teach that topic in the most effective way recommended for the achievement of the relevant objectives. The starting point is the course itself; not a catalogue from a supply house.

7.4 The following criteria may be useful in selecting equipment.

i. Choose equipment that can be easily modified or used for a wide variety of activities. Avoid items with only specialised or limited use. Check carefully, for example, how often a microscope would be *essential* in practical work for pupils aged 11 to 15 years.

ii. Carefully check that all schools have necessary facilities to make a particular item work. For example, there is no point in buying a filter pump that attaches to a water tap if the water supply to the classroom is by bucket from a well or village pump. There is no point in having bunsen burners if the only source of heat is a spirit lamp and there is no point in electrical apparatus that requires a 'mains' outlet, if the only power supply is a dry cell battery.

iii. Choose items that are robust, strong and durable and will stand up readily to handling by inexperienced pupils.

iv. Decide carefully on the degree of precision required in measurement. Do not recommend measuring instruments such as balances that measure to a degree of precision beyond that implied by the course. Do not, for example, suggest a balance capable of weighing accurately within 0.01 g if one accurate to 0.1 g will be adequate for the requirements of the course.

v. Always use equipment with simple and observable operating principles that can be seen and understood by average pupils. Avoid the 'black box' type of apparatus with mysterious and unseen working parts. The principle on which the apparatus operates must be known to the pupils and so only apparatus that uses principles or concepts mentioned in the syllabus, or related syllabuses, should be recommended.

vi. If the teaching strategy is to have pupils use the apparatus themselves, choose small compact equipment - 'semi-micro' chemical apparatus for example. If the strategy is to teach mainly by teacher demonstration choose large equipment seen easily by pupils from the back of a crowded classroom.

vii. Wherever possible choose equipment that is safe to handle. Avoid sharp-pointed instruments, jagged or sharp metal edges, breakable equipment, devices that use highly explosive or inflammable fluids or which require poisonous substances. For example, do not recommend glassware for field excursions - suggest instead metal or plastic containers for collecting specimens. Children running on slippery rocks, say, can have very unpleasant accidents if they fall while holding glass jars.

viii. Wherever practicable choose apparatus that can be used by the average teacher as a prototype for making this or similar equipment from locally available materials. In such cases supply teachers with instructions on how to make his copies of the prototype.

ix. When choosing between an expensive piece of equipment that, because of cost, could be supplied only one per class, as against a cheaper equipment that could be supplied one per pupil, choose the latter provided it meets other criteria - especially the criterion of durability.

x. Cheapness is not *of itself* a satisfactory criterion; but provided most other criteria are satisfied (especially strength and durability), then always choose the cheaper item.

xi. Choose items that require minimum maintenance and which can be corrected and repaired easily by the school teacher himself. Choose only limited equipment that has to be repaired by a central agency of the school system. Avoid, altogether, equipment that must be repaired and maintained by an agency outside the country.

xii. When two techniques are available for achieving a certain objective, choose apparatus for the simpler technique. For example, if the objective is to make a comparative (not absolute) estimate of the humidity of the atmosphere, recommend use of a strip of cobalt chloride paper or a human hair rather than wet and dry bulb thermometers with a conversion table.

xiii. Choose apparatus that is well suited to the degree of psychomotor maturity of the pupils. Avoid equipment that requires delicate or precise adjustment, fine readings or accurate positioning if the pupils do not have, at that stage, the practical ability to acquire such skills.

xiv. Choose, wherever possible, techniques and hence apparatus, that will appeal to children. Avoid equipment that requires tedious or repetitious actions - e.g. use direct weighing balances rather than conventional but tedious beam balances. Where possible recommend apparatus made of familiar local materials easily recognised and understood by pupils. Choose items that can be useful in motivating children - educational toys and puzzles; colourful rather than drab equipment; and familiar (local) rather than unfamiliar components in the equipment.

xv. Decide, for each piece of equipment, if there is a readily available local substitute that could be supplied free or almost free by the teacher or pupil, e.g. jam jars instead of specimen jars; cooking scales instead of chemical balances; sewing scissors instead of surgeon's dissecting scissors; empty bottles instead of Winchesters for stock solutions and so on. Recommend such substitutes, but try to supply a minimum stock of the especially manufactured equipment as a prototype.

xvi. Take into consideration storage, display and accessibility of equipment in the classroom. Choose apparatus that can be stored, selected from storage, displayed and distributed easily by the pupils themselves.

xvii. Choose apparatus that is compatible with other equipment. Consider the apparatus and equipment in the school as part of an over-all system. Make sure components are interchangeable from item to item; that even and uniform standards are set for pieces of equipment and each component of each piece. Do not, for example, buy a piece of optical apparatus with a lens system suitable only for that one item of equipment. Make sure these lenses can be used on other types of optical equipment.

xviii. As an extension of xvii, the system of apparatus for biology should also be thought of as part of a system for the school as a whole. It should be compatible, interchangeable with, and in fact part of the stock of equipment needed for other sciences such as physics and chemistry; and for other subjects such as domestic economy; geography or physical education. Unnecessary duplication in purchasing should be avoided.

xix. Carefully consider the effect of the local climate on apparatus. Check that apparatus will resist extremes of local climate and will operate successfully under such conditions. Moist humid conditions can effect certain optical and measuring equipment, cause rust and mildew, increase attack by insect pests or decay of wooden components; dry-hot conditions can cause expansion and distortion of metal parts, dry-rot of timber, etc. Climate is an especially important factor in choosing apparatus for growing and culturing organisms. A terrarium or a germination box designed for a temperate climate would probably be most unsuitable in a tropical climate. When tendering for apparatus always supply a range of manufacturers with a statement of operating conditions (including climatic factors) and choose the apparatus best designed for those conditions.

SECTION 8. Suggested List of Minimum Equipment for a Class of 25 Pupils Covering all Secondary Biology (Age Group 11-17)

8.1 As discussed in Section 7 (paragraph 7.3) there is no such thing as an 'agreed list' of apparatus suitable for all schools of secondary biology. Apparatus should be selected for specified topics, to help pupils in attainment of the objectives of the course and to help teachers develop recommended strategies.

8.2 The following list, therefore, is suggested only as a general resource. Curriculum workers should start, not with this list, but with the syllabus. Perhaps with the aid of the criteria given in Section 7, they should then build their own list of minimum requirements. The following check-list is only a source of ideas for apparatus needed for a specific course. Chemicals, other than those needed for particular pieces of equipment, have not been included.

Equipment	Quantity
Aquarium (medium size may be divided by sheets of glass)	4
Asbestos squares	25
Autoclave (pressure cooker)	1
Balance: direct weighing + minimum 1 set of weights	1
Balloons (toy)	10
Barometer (Fortin)	1
Basins: evaporating	12
Beakers, see Glassware	
Bosses: retort stand	50
Bottles, see Glassware	
Brushes: Camel hair	30
Cleaning	1
Test tube	5
Bungs: Cork	100
Cork borers + sharpener	1 set
Rubber	100
Bunsens (Important - state gas type when ordering + fishtail fitting)	12
Cages for small animals	5
Camera: not processing equipment	1
Cans (may be empty food tins)	50
Centrifuge: simple hand driven type + tubes	1
Clip boards: field notes	25
Clips: for rubber tube (Mohr type) (also screw type)	50
Paper clips: wire	1 box
bulldog	50

Equipment	Quantity
Clock: stop clock type	1
Cooling system: refrigerator or drip bag, etc.	1
Cotton wool	1 Kg
Crucibles: large porcelain	20
Desiccators	2
Dishes: white enamel approximately 12"	10
Electricity supply:	
Batteries	20
or	
Low voltage power supply	1
Eye dropper rubber bulbs (glass part may be made from glass tube)	50
Filter papers: various sizes	10 boxes
Forceps: pointed	25
blunt	25
Gas: cylinder gas (propane, butane, etc.)	2
Glassware: Standard types not usually required by students. Teacher may also need Standard set of calibrated equipment for preparing solutions.	
Beakers: 1 l.	5
500 ml.	50
250 ml.	50
100 ml.	50
Bottles	100
Filter funnel 3"	50
Flasks volumetric	2
Glass rods	30 metres
Glass sheet 1/8" thick, various sizes	12
Glass tubing (soda glass) standard and capillary	30 metres of each diam.
Measuring cylinders:	
500 ml.	5
100 ml.	10
Preserving jars for specimens	100
Specimen tubes 4"x1"	500
Test tubes, various	500

Equipment	Quantity
Glue: paper paste	6 pots
rubber contact adhesive	6 tubes
Graph paper	5 reams
Gummed tape (paper or plastic)	6 rolls
Hydrometer set	1
Hygrometer (sling type or hair type)	1
Cobalt chloride paper (may be dried for re-use)	2 boxes
Insect box (improvise)	25
Killing bottle	12
Knife: 8" to 10" blade	1
Lenses: hand magnifier	25
large surface x 10	
large dissecting	25
Mercury for Barometer	200 cc
Metre rules	50
Microscopes: compound	25
stereo binocular	25
+ Lamps	25
Mortar + pestle (porcelain type or glass type)	2
Needles: mounted	25
Net: dip	25
butterfly	25
aquarium (tea strainer)	2
Oven: incubating	1
drying	1
Pencils (wax marking)	12
Petri dishes, glass and disposable plastic	100
pH measuring equipment:	
Paper: wide range	1 cassette
full range	1 cassette
narrow range	1 cassette
Universal indicators (liquid)	1 bottle
Comparator type (colour)	1
Pins, large: dissecting and insect pinning	1 box
Plant pots: disposable	100
Plastic (polythene) bags various sizes	100

Equipment	Quantity
Polythene bottles (large) wide neck for field trips	12
Polythene buckets: see Troughs	
Press: plants preserving	1
Racks for test tubes (can be home made)	25
Retort stands	50
Rubber bands, various sizes	2 boxes
Scalpel:	25
Hone	1
Strop	1
Scissors: pointed	25
blunt ended	25
Sieves 10, 20, 40, 60, 80, 100 mesh	1 set
Slides 3 x 1	1000
and Cover slips	1000
Solar still or de-ionized water supply	1
Solder, soft-hard (only if gas available), soldering iron: electric or gas	¼Kg
Spade: small for field work	1
Spirit lamps: metal body	10
String, strong light weight	1 ball
Syringes, plastic disposable and needles	12
Terrarium: plastic	4
Thermometers 10°C to 110°C	50
Thermos flask	12
Tongs: metal	25
Tongue depressors: spatulas	500
Tools:	
bench vice and clamp mounted on block of wood on bench	1
chisels	1 set
drills (engineers) 1/32" to ¼"	1 set
files flat	1
half round	1
round	1
triangular	1

Equipment	Quantity
hack saw	1
glass cutter (diamond)	1
glass knife (for tube)	1
medium size adjustable spanner	1
plane	1
tenon saw	1
tin snips	1
Torch, flashlight and batteries to suit	2
Trays, small plastic photographic type	50
Troughs, large earthenware to hold bench waste, not required if sinks are fitted; or polythene buckets	6
Trowel	1
Tubing, rubber and plastic various diameters, minimum length of each	20 metres
Vaseline 500 g.	1 tin
Vermiculite	50 Kg
Wash bottles, plastic	25
Watch glasses, use Petri dishes	
Water bath for temperature controlled experiments (may be improvised)	2
Weights - see Balance	

SECTION 9. How to Plan and Write a Curriculum and Teachers' Guides

9.1 After the construction of a syllabus (Section 4), it must be made into a curriculum. Curriculum can be defined very broadly as "that which happens in a classroom". Converting a syllabus into a living and dynamic curriculum is a continuous process. The objectives having determined the content of the syllabus, materials must be produced and teachers trained to implement the new programme. The "curriculum in action" must be continuously evaluated and tested to check on its effectiveness in achieving the objectives. As a result of this evaluation the whole situation must be re-appraised, leading continuously to re-definition of objectives; refinement of the syllabus; and to modifications of learning materials and teacher education. These adaptations must themselves be re-appraised and evaluated and so the process is continuous.

9.2 In this section the over-all plan of the curriculum is discussed, with special reference to curriculum resources and to aiding the teacher by developing teachers' guides.

9.3 The first step after the determination of a syllabus is to arrange its topics into a teaching sequence or programme. This sequence should take into consideration the following factors.

i. The need to cater for an increasing level of maturity from ages 11 to 17 accompanied by increasing selectivity amongst pupils due to more and more leaving school as the grades increase.

ii. The recommendation (Section 4.11) to devise a linear, but well articulated, basic structure with concentric development of major concepts or themes.

iii. The need to cater for individual differences by including, where appropriate, optional sections.

iv. The demands of employers or further education authorities at various key points along the educational ladder from age 11 to 17.

v. The need to build 'transfer bridges' of content, objectives, and method to other areas of the curriculum in each grade or year.

vi. The availability of curriculum materials.

vii. The need to cater for regional differences in objectives and in resources.

9.4 The next step is to produce materials for the programme. By far the best way is to divide the programme into reasonably small units or topics and to produce materials for each of these as a series of *learning resource units*. This is what in fact has been started in the case of the "Unesco Pilot Project on new Approaches and Techniques in Biology Teaching in Africa". The materials produced so far by this project form the nucleus of resource units on specified topics. The value of this unit approach is that it maintains flexibility in the teaching sequence so that the syllabus can be programmed to cater for differences between individual pupils, allowing for regional modifications and catering for differing resources. The units can be of increasing sophistication over a broad number of units so as to provide for deepening knowledge and understanding.

9.5 A most essential component in a resource unit is the teachers' guide or manual. This interprets the unit and provides a key to locking together the various teaching resources into an over-all system.

9.6 Planning Materials for the Pupils

(a) Texts, Study Guide and Practical Manual

For the pupil the central resource is the printed text. Local groups may consider using the Unesco units as models for the production of other texts with more definite local orientation, to fill out the over-all programme or to provide alternatives. The content of each unit will, of course, determine the specifications of the other resources.

The following technique for writing texts has been developed in Australia by the present author. Recognising that each country has its own individual objectives and resources it has been included here only as a guide for local action. It is based essentially on team co-operation.

A WORKSHOP TECHNIQUE FOR WRITING BIOLOGY TEXTS

A. Teacher Workshop Group (Author Team):

MAIN TASK : To write the basic content and to have over-all control, co-ordination and supervision of the text.
PERSONNEL : 3 to 5 master biology teachers, plus others (see B).
ACTIVITIES :
1. Work during school vacation, or on specified days over an extended period, usually a year.
2. Work may be voluntary, paid or result in royalties.
3. Functions as writers, co-ordinators and editors.
4. Develops the outline, the initial and final manuscripts and supervises publication.

B. Academic Monitoring Group (Biology:Educators/Biology:Resource Personnel):

MAIN TASK : To review and approve all material for scientific accuracy as requested by the author team.
PERSONNEL : Lecturers from teacher training institutes; teachers of biology in universities and research workers in biology.
ACTIVITIES :
1. Used at all stages of manuscript development - including practical work, illustrations etc. to check for biological accuracy.
2. More than one of this group are usually members of the author team.

C. Educational Monitoring Group (Educationists/Curriculum and Psychology Resource Personnel):

MAIN TASK : To review materials produced in the light of accepted educational criteria.
PERSONNEL : Educationists skilled in techniques of curriculum, educational psychology and communications.
ACTIVITIES :
1. Reviews objectives and criteria for choice of content.
2. Reviews and approves approach for age and grade level.
3. Reviews and approves communication technique (word usage, size of print, colours, etc.).
4. Reviews and approves the learning theory applied to various concepts for age, ability, and school level intended.

D. Technical Resources Support Group (Administrative and Technical Personnel):

MAIN TASK : Clerical and technical production.
PERSONNEL : Clerical workers and audio-visual technicians.
ACTIVITIES :
1. Collates draft manuscripts.
2. Produces prototype illustrations.
3. Provides a staffed laboratory for 'try-outs'.
4. Produces prototype audio-visual aids to supplement the text.

(continued)

E. Educational and Technical Materials Resource Group (Library Personnel):

MAIN TASK : To collect print and non-print resources into the curriculum laboratory used by the Teacher Workshop Group.

PERSONNEL : A trained librarian assisted by a member of the author team and a curriculum expert.

ACTIVITIES :
1. Collates relevant curriculum outlines - national and international.
2. Selects relevant text books on both content and method.
3. Collects relevant evaluation instruments - tests, measurements, observational studies and surveys with relevant data.
4. Selects appropriate and relevant Teachers' Guides.
5. Selects and displays appropriate audio-visual aids.

F. Publication Group (University, School, Government or Commercial Publishing Personnel):

MAIN TASK : Publication of the texts.

PERSONNEL : Trained publishers working with and co-ordinated by the author team.

ACTIVITIES :
1. Chooses paper (size, quality and cost).
2. Organises printing (type-size and readability).
3. Decides on cover and binding (design, type, durability).
4. Chooses size and format of book.
5. Supervises reproduction of illustrations and photography.
6. Selects and supervisesuse of colours.
7. Undertakes market analysis and distribution arrangements. Decides on unit cost, etc.

ii. Whatever techniques are used for writing texts (integrated team, small group or individual author) there is a growing tendency to make a text more than just a statement of content. Most modern texts are also Study Guides. They help pupils learn the content. They provide vocabulary lists, summaries, suggestions for further reading, suggestions for activities, ideas for discussion, and opportunities for "self-check" evaluation of progress in achievement through questions and tests. Some, such as the Unesco Biology for Africa Units, also include practical work so that the learning activities are smoothly sequenced and integrated. In others, the practical work is developed separately in a parallel book which is usually produced as a work-book in which answers are to be written. This latter technique is not the best method since it can cause interference in learning, due to discontinuity.

iii. The combined text/Study Guide/Practical Manual should be simply written, logically organised and well and clearly illustrated. The over-all unit should begin with clearly stated objectives and each sub-unit should have stated behavioural outcomes. The suggested activities should be as open and unstructured as possible to provide opportunity for creative discovery. Instructions for practical work should be clear, logical and unambiguous. Full details of technique should be given when it is required for the solution of a problem, e.g. steps in a dissection should be set out in logical order and illustrated by drawings and photographs. Equipment required for the activity should be listed. Questions should be of two types: firstly, those that require logical recall of information and facts organised to provide an over-all summary; secondly, those which test the achievement of specified objectives and general objectives such as those of Bloom's taxonomy (comprehension, application, analysis, synthesis and evaluation). Because questions are mainly included for self evaluation, answers should be provided or an indication given as to where the answer can be found. Questions for discussion should be provocative and stimulating. The reading lists should be annotated and include only readily accessible publications at an appropriate level for pupils. A comprehensive classified index should be provided and the book should have a well organised table of contents. Layout is important. Size of page and type should be carefully selected for maximum readability and there should be a high proportion of 'white space' on each page. The amount of information on each page should be kept as low as possible - perhaps to one central idea only.

(b) Supplementary Reading Material

There is an increasing world trend to provide a series of paper-back booklets to accompany main texts. These may select a topic mentioned in the text and develop it at greater depth. They may be based on related topics to those of the text and so provide additional enrichment for able and interested pupils. They may select classical case-studies of great discoveries in biology - often using the writings of the biologist concerned. They serve to provide motivation and enrichment and help to cater for individual differences by providing alternatives in the curriculum.

(c) Additional Tests and Questions

Apart from the questions in the text itself it is useful to supply pupils with regular self diagnostic tests containing both objective short-answer and open-ended questions. These help both pupil and teacher assess degree of mastery of the course and also provide useful resources for discussion and further learning. (For test construction see Section 10).

(d) Apparatus Kits

Some current curricula issue complete kits of apparatus with instructions and study guides for particular activities specified in the course. Such kits are especially valuable in schools lacking conventional apparatus and equipment or in classes taught by un-trained teachers. They do, however, impose a degree of uniformity and the aim should be rather to provide each school with flexible technical resources that can be adapted for the needs of particular projects. Generalised rather than specialised kits should be supplied (see Sections 7 and 8).

(e) Programmed Materials

Short units of either linear or branched programmed instruction provide useful curriculum resources for pupils. They can be used to develop particular skills or provide specific information for the solution of a problem. They help cater for individual differences by giving able students opportunities to study certain topics in depth or to acquire special skills. Programmed instruction can also be used for remedial work with less able pupils. Teaching machines are probably unnecessary and simple programmed pamphlets are both economical and generally successful.

(f) Visual Aids

The most effective of modern visual aids are 35 mm colour slides or strip films; overhead projector transparencies; Super 8 mm reel to reel movies in cassettes; and 16 mm sound and colour movie films. More complex aids such as television and computers are beginning to influence teaching technique but must be considered very carefully in school systems with relatively restricted budgets.

In planning visual aids, reference should be made to published criteria. I would especially stress however, relevance, enrichment, reinforcement and extension of experience. Care should be taken to provide links with the central resource (i.e. text/study guide/ practical manual). The aids should emerge from and be integrated with the text and its ancillary materials such as the supplementary readers, tests, or programmed pamphlets.

(g) Audio Tapes

With the development of cassette tape recorders and players the cost of tape recordings has been greatly reduced. Tapes can now be introduced as curriculum resources into many school systems. Like the visual aids, they should be planned to develop from the texts and practical manuals and can be used effectively to provide information or to train in technique. Linked to other media, such as Super 8 mm movie films or 35 mm slides, they are powerful aids to learning, especially for pupils who learn better by observing and hearing than by reading. Tape recordings also provide a useful central medium for integrating a number of other materials (see (h) below).

(h) Integration of Resources for the Pupil

A current trend is to develop all the learning resources of a curriculum into an integrated system, and this is good educational practice provided the system is sufficiently flexible. There is a rapid development of multi-media learning systems such as audio-tutorials which combine together by means of information and instruction recorded on audio tape, activities involving printed materials, programmed units, films, 35 mm slides, practical apparatus, and even field excursions and discussion groups. Whether such "multi-media packages" are relevant for all school systems or not, their development emphasises the need to look at all the resources of the curriculum as *one*; to see all of them contributing by reinforcement and enrichment, to the achievement of the objectives of the programme. The teacher must be given help in this task of integration and the Teachers' Guide or Manual has a key role in this.

9.7 Planning the Teachers' Guide

i. The Guide should be produced in volumes or units corresponding with the broad divisions of the school grades. In the case of the Unesco Biology for Africa Project, probably three volumes would be best - one each for Lower School, Middle School (ending with the O-Level (SC) Examination) and A-Level. This system keeps together relevant graded material, retains flexibility, and makes the one guide available to three teachers at the one time.

ii. The first volume should contain an over-all statement of the philosophy of the course. It should state and discuss the objectives; give a summary of the main content with the rationale for choosing each topic, and discuss and explain the recommended teaching strategies. Each volume should also include a section on special problems and interpretations for the particular grades concerned.

iii. The main part of the manual should give specific advice on the teaching of each topic or unit specified for the grade. The following headings may be useful:

(a) *Assumed Knowledge:* A statement of the pre-requisite knowledge, understandings and skills that pupils would need to understand the topic. Advice on assessing this standard and on remedial action necessary to bring the pupils to the required level.

(b) *Purpose of Unit:* A statement of the general and specific objectives and behavioural outcomes recommended for the unit. Some discussion of points of special emphasis in the teaching and a brief summary of the rationale for the manner of presentation adopted in the text.

(c) *Comments on Text:* These could be interpretations or elaborations of concepts in the text. In this section, too, precise instructions for and advice on organising and setting up experiments and other specified practical work could be included. This section should be liberally illustrated with photographs and line drawings.

(d) *Additional Activities:* Teachers should be advised on additional practical work and other activities. These are important to provide enrichment to allow alternatives in the curriculum and to cater for individual differences. Full instructions should be included and the section should be illustrated by diagrams and photographs.

(e) *Teaching Aids:* Sources of aids and advice on the use of aids should be listed under the following headings:

special laboratory kits
models
charts
prepared chalkboard/flannelboard/pegboard
8 mm films
16 mm films
35 mm slides and strip films
books and pamphlets
magazine articles
programmed materials
audio tapes
other aids

(f) *Biographical Notes:* A very short summary of the lives and careers of each biologist mentioned by name in each unit (illustrated by quotations from writings by the biologists concerned).

(g) *Answers to Questions Included in the Text:* It is important that all questions in the text should be fully answered and discussed in the Teachers' Guide.

(h) *Additional Questions (with Answers) not in the Text:* It is useful to provide teachers with a reserve of additional questions, preferably involving understanding rather than mere recall of facts. Answers to these questions should be provided.

(i) *Topics for Discussion:* Topics for class discussion should be recommended. These should be on broad speculative issues about man and his environment.

(j) *Sample Test Questions:* A range of objective and short-answer type questions should be included for building tests and examinations. Answers should also be provided.

vi. The rest of the manual should contain discussions of general problems and techniques of biology teaching. Topics for discussion in this section may include:

care and use of the microscope
care and use of balances; spectroscopes and spectrometers; vacuum pumps; and barometers
elementary glass work
safety precautions in the laboratory
advice on simple bench work - soldering, etc.
preparation and supply of stock solutions
biological stains and staining techniques
animal dissection; techniques and care and use of instruments
killing and preserving animals
making a herbarium collection
organising a school museum
organising displays
using the school garden to teach biology
procedure for field excursions and visits away from the school
general references and resources

SECTION 10. Construction of Achievement Tests and Statement of Objectives for Classroom Trial and Assessment of an Experimental Biology Teaching Programme

10.1 Section 1 of this Guide outlines the need for and the objectives of classroom trials of experimental materials. In that section it was recommended that data be collected from observation of lessons; and directly from teachers and pupils. For pupils it was suggested that there should be assessment of interests and attitudes by means of written essays and from observations of behaviour. It was recommended too, to assess achievement in knowledge and understanding. This section of the Guide recommends procedures for constructing tests of achievement in knowledge and understanding of major concepts.

10.2 The first step is to choose the form of the questions. Objective testing is probably the quickest and most reliable way of collecting the considerable amount of information necessary for over-all appraisal of a new programme. Of the various objective styles, the multiple choice item is possibly the most effective and easily controlled for the purposes of such a survey. Evidence is in favour of four alternatives in each multiple choice question since this reduces the verbal elements in the test. It should be understood, however, that while well designed objective tests can indicate over-all attainments; can rank children reliably on degree of achievement and indicate over-all differences between groups, they do not give much information about weaknesses and problems of individual pupils. They also cannot effectively test what Bloom calls "synthesis" i.e. ability to put together different items in new combinations resulting in creative products. Multiple choice questions, therefore, while forming the main test instrument for group data and for over-all trends, should be supplemented by open-ended creative questions. Such open-ended questions give opportunities, too, for general expressions of attitudes and interests, and such evidence should be noted with care. Answers to open-ended questions should be assessed somewhat impressionistically to help determine over-all tone and degree of achievement of objectives.

10.3 Having determined the form or forms of test items the next step is to list the specific objectives to be assessed. Probably, for checking mastery of knowledge and understanding concepts, the best set of objectives would be those specified by Bloom in the first volume of his taxonomy. These are:

(a) *Knowledge:* The facts that can be remembered. A test of knowledge requires little more than bringing to mind information that has been learned. Bloom recognises three types of knowledge: of specific facts; of ways and means of dealing with specific facts, and of principles, generalisations and theories and how they are related. Probably, the ability of pupils simply to recall facts of the new course, is not of itself, a very significant test of effectiveness of the programme. There are more important objectives, and therefore the test should include few (if any) items assessing knowledge alone.

(b) *Comprehension:* Involving more than knowledge. This implies a recognition and understanding of known facts in situations similar to but different from those in which the facts were first learned. There are three kinds of comprehension. The first is *translation* of information from one form to another; words to graphs; symbols to words; formula to words, etc. The second is *interpretation* which requires a recognition of known facts when they are re-ordered, re-arranged or looked at in a new way. The third is *prediction* which involves determining future trends such as in the extrapolation of a graph or continuing a trend in a table of figures. Comprehension is an important objective and should be stressed in tests of course effectiveness.

(c) *Application:* Deeper understanding than comprehension. It involves the application of abstract ideas such as principles, theories or laws which are known and comprehended, to the interpretation of particular situations. For example, given the results of experiments on cross-breeding of plants, pupils would be asked to interpret the results through an application of Mendel's laws.

(d) *Analysis:* Involving the identification and sorting out of parts of a particular situation or block of knowledge. There are three aspects of analysis. The first is the identification of parts of a situation; the second is recognition of the way the parts are connected and interact, and the third is the identification of the principle or principles used to bring the parts together. Analysis is clearly a major objective of a modern course in biology and should figure prominantly in any test of its effectiveness.

(e) *Synthesis:* Putting together parts in such a way that a new system, pattern or structure that was not there before, is created. There are three types of synthesis. The first is the preparation of an essay or statement which communicates to others ideas, feelings or experiences in an organised or logical way. The second is the production of a plan or scheme for undertaking a certain task; for example, the design of an original experiment. The third is the production of a new idea by studying and bringing together in an original way, previously unrelated facts or ideas. Problems involving synthesis cannot be effectively tested by multiple choice questions. Synthesis, however, is a vitally important objective in a meaningful science course and so should be tested by open-ended creative questions.

(f) *Evaluation:* Involving making judgments about the value of materials and methods for specific purposes. Pupils must make decisions as to whether or not given ideas, objects or methods are appropriate or effective for the purposes for which they were intended. The evidence used by pupils to reach decisions may come from situations as given in the question or through knowledge and understanding from other sources. Evaluation is a major objective, giving opportunities to assess transfer and development of value systems in children. Unfortunately, good objective items testing evaluation are very difficult to construct. Some evaluation questions, however, should be included if possible.

10.4 Decisions about test items and objectives having been made, the next phase is to decide on the scope of each test. Probably in courses consisting of flexible and interchangeable units (such as those based on the materials of the Unesco Biology for Africa Project), a unit test should be produced for each text booklet. Probably, in order to give a fair coverage of content of a unit, fifteen multiple choice items should be included testing knowledge, comprehension, application, analysis and evaluation. There should also be a short open-ended question to assess synthesis.

10.5 The next step is to prepare precise specifications for the unit test and this involves the construction of a *specifications grid*. The procedure is as follows:

i. Carefully look through the booklet or unit of work to be tested identifying the main ideas or concepts.

ii. List each sub-heading in the text and decide if the headings correspond sufficiently to the main concepts and ideas identified in step (i). If necessary, modify the list of headings to include all the major concepts of the unit.

iii. If the list includes more than fifteen concepts, reduce the list to fifteen categories by grouping together related topics or ideas.

iv. If the list has less than fifteen concepts decide which are relatively more important for the objectives of the course and give these double entries until you make the list up to fifteen.

v. Analyse the book carefully to see if the mental skills; knowledge, comprehension, application, analysis and evaluation, are stressed. List those that reflect the objectives of the text.

vi. Prepare a grid with the concepts listed as the left hand column with mental skill objectives across the top. For example the grid for the fifteen multiple choice items for the unit test on Part I of the Unesco Pilot Project "*The Living World Around Us*" might look like this:

QUESTION	CONCEPT	OBJECTIVE: Knowledge	Comprehension	Application	Analysis	Evaluation
1	Concept of habitat					
2	Differences and similarities					
3	Grouping familiar objects					
4	Grouping animals					
5	Grouping animals by structure +					
6	Grouping animals by structure +					
7	Concept of a key					
8	Using a key +					
9	Using a key +					
10	Making a key					
11	Concept of classification +					
12	Concept of classification +					
13	Scientific training					
14	Concept of species					
15	Main groups of living things					

+ *Considered sufficiently important to be tested by two items making test up to agreed fifteen questions*

vii. Now write the first question of the examination so that it tests the first of the listed concepts and any one of the stated objectives. When the question has been set have it checked by colleagues. If they agree that it fairly tests your declared objective and is relevant to the concept concerned, place a tick in the grid against the concept and under the objective. For example in the case of the following simple question, a tick would be placed in line 1 under Knowledge because the item only requires pupils to recognise that the word habitat is the term for natural place where an organism lives.

Question: *Four boys were fishing in a river. They caught some fish and were reminded of a new word they had heard at school that day. The word was habitat. They talked about the habitat of their fish. The boy who had the best idea of what was meant by the new word said that the fish was in its habitat when in a -*

A. *lake*

B. *fish tank*

C. *preserving jar in a museum*

* D. *river*

Another rather easy question on the first concept could be as follows:

Question: *Read the following part of a book on snakes and then answer the question following it.*

"In tropical jungles some snakes live in damp soil, and others live in trees. In deserts and grasslands snakes live mainly in burrows. Good places to find land snakes are in hollow logs, beneath stones or bark and under sheets of tin left lying around and undisturbed. Some types of snakes also live in water, but these are not so common".

This part of the book on snakes is mainly about their:

A. *biological classification*

* B. *habitats*

C. *numbers*

D. *body heat*

In this case, however, you may place the tick in line 1 under *analysis* because it requires pupils to recognise the main idea or theme of the quotation. It is, of course, a very easy example of an analytical question. Such questions can be made much harder by developing more complex situations.

viii. Move now to concept number 2 and repeat step (vii) and so on until all fifteen concepts have been covered. Try as you do this, to produce what you consider to be a correct balance of objectives. Hopefully few items will test knowledge alone. Probably most will test comprehension, application and analysis.

ix. Look over your grid and check that all the objectives are fairly represented in proportion to your original ideas about their relative importance. If any have been omitted or under-stressed, or if some objectives have been given too much stress, replace some of the questions to make the grid more representative.

x. Now set an essay-type question to test synthesis. It should state what concepts you want synthesised, suggest sources of ideas, and describe the length and nature of the product required. For example, from the grid above you might decide to test synthesis of concepts 1, 5, 7 and 8 in the following way.

Question: This question is about habitats, groupings of animals and about biological keys. Suppose your classmates went out to collect animals and came back with twelve altogether: four from a tree in the garden; four from a pond and four from the soil just outside the classroom. They did not know the names of the animals and so labelled them A to L. The photographs of the animals are shown below.

Photograph	*I*	*tree*	*A B C D*
	II	*pond*	*E F G H*
	III	*soil*	*I J K L*

When these three collections were brought into the classroom they were accidentally mixed together.

Make a biological key to help other pupils work out the original habitat of each animal in the collection.

Discuss whether a key to habitats would be as generally useful as a key to animals themselves. To help you answer this, think about how most biologists use keys and what knowledge they usually have of places where animals live. Write about half a page on this part of the question.

xi. Having made the first draft of the unit test try it out with a class of pupils. Watch for level of difficulty, type of language, ambiguous questions and so on. It might be, for example, that the question testing synthesis may prove far too difficult altogether for the level of achievement and general ability of almost all pupils. Questions should then be modified as a result of this trial, and the unit test duplicated in its final form.

10.6 A final point. It is important to remember that the purpose of this testing is not to grade pupils or to diagnose an individual's general problems of personality or learning. The purpose is to assess the effectiveness of the course! *The people being tested are not the pupils but the curriculum makers!* They should respond to the results not with negative criticisms of teachers and pupils but with a desire and a willingness to modify the objectives, the content, and the recommended strategies, in view of evidence obtained.

SECTION 11. An Example of Outline of Content of a Modern Secondary School (Age Group 11-17) Biology Teaching Programme

11.1 The following scheme is one developed by the author as an attempt to meet the objectives of modern biology and which utilises resources made available by the International Working Group of the Unesco Pilot Project for Biology Teaching in Africa. It is submitted only as a stimulus for discussion.

Continuing (Concentric) Themes

1 2 3 4 5 6 7 8 9 10 11 12 13

(1) Man's Environment
(2) Process of Science
(3) Interdependence & Conservation

11.2 Lower School

(a) Requirements of Life

differences between the living and non-living (man as the example)

what man needs to keep him alive and well

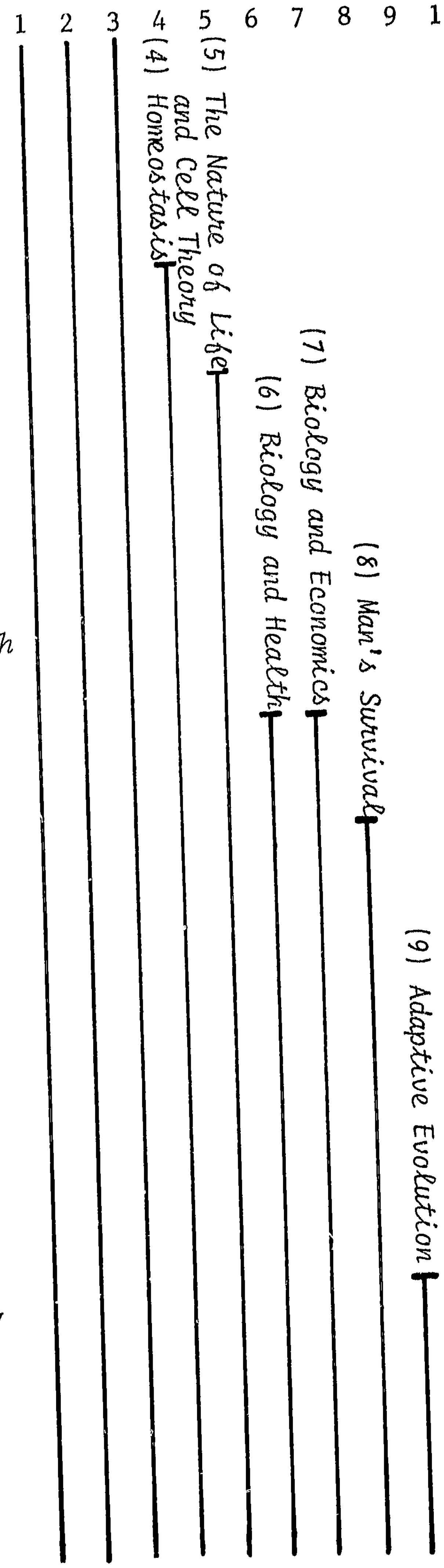
light - the source of energy for life

plants as producers

animals as consumers (implications for man)

Continuing (Concentric) Themes

1 2 3 4 5 6 7 8 9 10 11 12 13



biological cycles in nature (relate to man)

(b) The Human Body

the structure and function of the human body

cells and their chemical and physical requirements

how the systems of the body are co-ordinated

self-awareness, individuality - the differences between people

(c) Man's Relationships with Nature

problems of disease and old age

the growing human population and its problems

man exploits nature - basic principles of agriculture, fisheries and forestry

problems of pollution and conservation

11.3 Middle School

(a) Man's Place in Nature

places where living things occur (sea, freshwater and land)

the adaptive diversity of living things

the place of man in relation to other living things

man's origin and evolution

Continuing (Concentric) Themes

1 2 3 4 5 6 7 8 9 10 11 12 13

(10) *Origin of Life*

(11) *Explanations of Diversity*

(b) *Communities of Living Things*
the origin of life in the sea

barrier of the rocky shore and the pathway to the land via estuaries, rivers and swamps

the spread of living things on land, desert, rainforest, grassland and tundra

man's influence on biological communities

(c) *The Story of One Biological System of Importance to Man*
lake or marine fisheries; agricultural field; forest

management problems and economic conditions, over-exploitation etc.

11.4 A-Level

(a) *Life has Continuity and Change*
Mendelian genetics and its implications

growth and development of living things

mechanism of evolution

(b) *Life Processes can be Explained at the Cellular Level*
levels of organisations: molecules, *cells*, organisms and populations

release of energy in cells

control of cellular processes by DNA

origin of life

(c) *Populations Change*
birth rate and death rate

components of environment that effect a population's chance to survive and multiply

local case studies of changes in distribution and abundance

an over-view of man's place in nature; especially considered in light of principles of population ecology

(d) *Organisms Respond to Their Environment*
review of nervous physiology

unlearned behaviour

learning, especially in vertebrates, with man as a case study

(e) *Special Problems of the Future*
feeding the human population

training for new vocations

conquest of disease and old age

creating new life

controlling populations

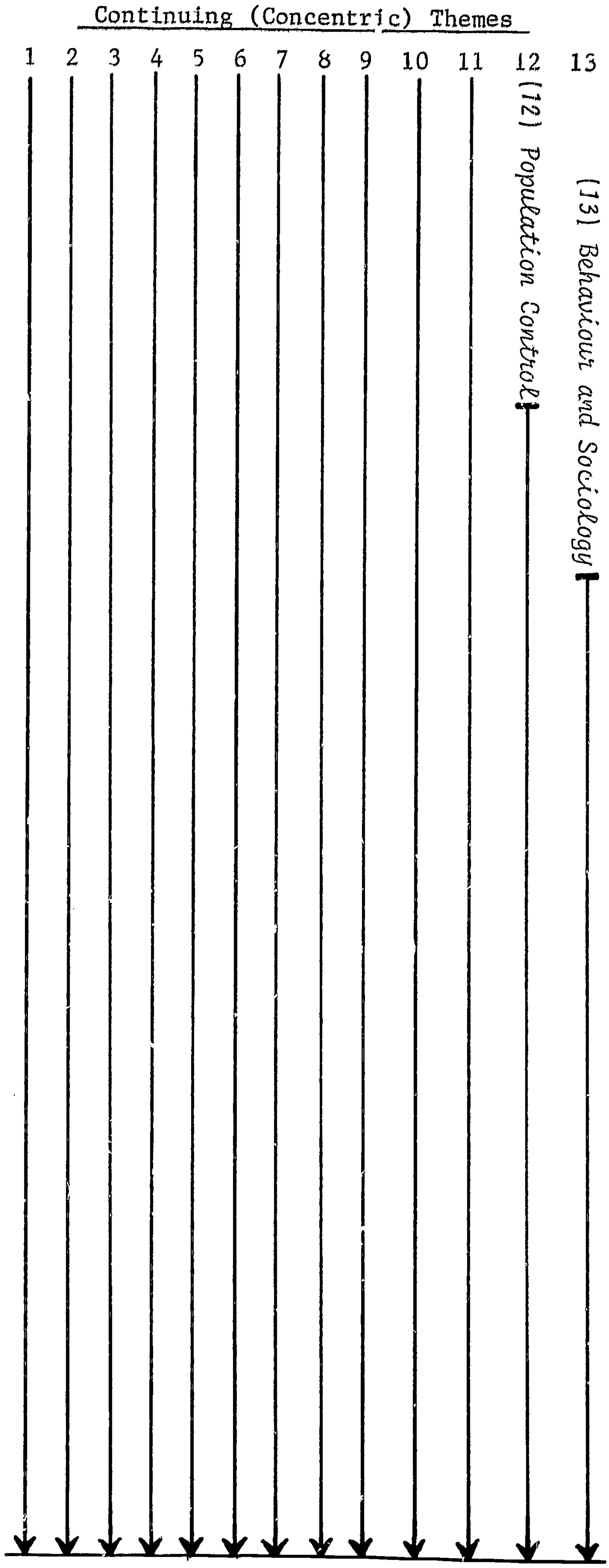
engineering the environment

conquering space

conserving resources and finding new resources

developing an understanding of man (take problems of race)

science and international understanding



SECTION 12. Outline of Out-of-School Activities for Pupils

12.1 A course of modern biology that has chosen as a major objective, to develop an understanding of man's relationship with his environment, should stress as a teaching strategy, excursions and visits away from the school. An understanding of environment can only come from experiencing this environment directly and personally.

12.2 The following procedures are recommended for the successful organisation of an excursion(1)

(a) Preparation

i. In the case of a field study, make a survey of the area before taking students. Get to know the major geological and biological features and select the best spots for collecting or observing plants and animals. Remember though, that a class will always find more than a teacher working alone. In the case of a visit to an institution assess carefully the features of biological interest in the place you plan to visit.

ii. Always have a specific aim and give the class adequate preparation. Do not attempt too much on any one excursion and remember purely descriptive records of animals or plants or of industrial processes are not very worthwhile.

iii. Have a list of questions or simple problems prepared so pupils can later answer them in the field while working in groups.

iv. Instruct pupils on the type of clothing to wear. It may be necessary for them to wade. Old sandshoes and shorts are recommended for the seashore and strong boots and slacks for the bushland.

v. If you are to visit a field area take a first aid kit.

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(1) Adapted from a contribution by the present author to a publication of the Nuclear Research Foundation School Certificate Integrated Science Textbook Group *Science for High School Students Teachers' Manual* (University of Sydney 1964) and reprinted here by permission

vi. Make definite arrangements with the school principal and staff. Obtain written authorities from parents to take pupils into the field. Ensure that parents accept responsibility.

vii. Organise transport, either through parents or local service clubs. Use either government or private buses or arrange for pupils to travel on bicycles. Remember though, to make maximum use of places near the school - the school grounds themselves are often useful.

viii. Issue students with lists of special equipment required (camera, notebook, lens).

ix. Obtain permission to enter private property.

x. Instruct pupils not to pick flowers or collect animals. Be strict about conservation. Obtain permission to enter national parks and reserves. Make sure pupils know the conservation laws.

xi. Do not take glass into the field. Use plastic containers and collecting jars. Serious accidents can occur with broken glass, on rock surfaces.

xii. Go on seashore excursions only at low tide.

(b) Conduct of the Excursion

i. There should be two teachers to share responsibility.

ii. Be most careful about safety. Some places such as railway cuttings, road cuttings, cliffs and rock platforms can be dangerous and pupils should be given repeated warnings. Particular care should be taken to observe the safety regulations of industrial institutions visited.

iii. Pupils work best in small groups - five with a group leader.

iv. Keep your objectives in mind - do not let the excursion degenerate into a walk through the bush or along the sea-shore or into a social outing to the town. It should be just as methodical as a laboratory class.

v. Observations should be recorded in a notebook, the reporter type book is the best for this. Perhaps book and pencil could be hung around the neck. A clip-board is useful for attaching printed assignments and pro-formas.

vi. Make sure the group leader takes responsibility for issuing and returning special equipment.

vii. In the field, collect the minimum plants and animals. Draw as many as you can in the field and return them to rock pools, streams, etc. Only take back a small representative collection to the school. Do not collect anything that is at all rare.

viii. Encourage use of cameras and sketch pads.

(c) Follow-up Lessons

i. Have a follow-up practical lesson as soon as possible. Sometimes it is useful for teachers to issue a cyclostyled summary of the main findings. Pupils can paste this into the practical book and add photographs and drawings, and can write their own conclusions.

ii. Try to get pupils to assess the extent to which excursion aims have been fulfilled.

iii. Develop and refine various hypotheses from the results. Plan experiments and further observations to test these hypotheses.

12.3 An outline of out-of-school activities is presented below, grouped under "concept" headings. No recommendations have been given on level or grade, because depth of treatment can be modified for different ages and backgrounds. Most of the activities, however, are suitable for Lower and Middle School.

12.4 *Concept I. There is a diversity of organisms adapted for life in a variety of habitats.*

Suggested Activities:

i. Visit a small stream and separately collect animals and plants from: (a) isolated pools containing rotting plant material; (b) slowly flowing pools; (c) races and small waterfalls. Arrange organisms from each place (by structure) into major groups. Look at the way they are adapted for feeding, breathing, swimming or resisting being swept away by the current.

ii. Choose one group of animals such as insects and collect them from: (a) soil and litter; (b) rotting logs; (c) trees and shrubs; (d) freshwater ponds; (e) fast-flowing streams. Try to work out the special conditions of the environment in each place (temperature, moisture, light, other organisms, etc.). Study the way the organisms are adapted to the conditions in each place.

iii. Visit a rocky seashore at low tide. Study (no collecting) the variety and structure of animals and plants in the following places: (a) in rock pools; (b) on exposed sun-baked rocks; (c) under moist boulders; (d) at the edge of the surf. Relate the adaptive features of the animals and plants to the environmental conditions of the places where they live.

iv. Visit a ma grove swamp at low tide. Study (no collecting) the variety and structure of animals and plants in the following places: (a) in pools left by the tide; (b) burrowing in mud; (c) on roots (especially pneumatophores) of the mangroves; (d) on the shoot system of the mangroves. Relate the adaptive features of the animals and plants to the environmental conditions in the places where they live.

12.5 *Concept II. Biologists can classify and name animals and plants according to their structures.*

Suggested Activities:

i. Given lists of the external features characteristic of major phyla, during an afternoon observe as many plants and animals as possible in an area near the school. List the popular or local names of each organism under its phylum and indicate the characteristics that helped in the grouping. Review the overall collection and discuss the possible reasons why some groups may be represented by a greater variety of organisms than others.

ii. Collect as many different members as possible of only one group (such as algae, flowering plants, insects, molluscs or worms) from *one* of the following places: (a) rocky seashore; (b) canopy of a forest; (c) grassland; (d) stream or pond. Give each specimen a common name or number. Using only their external features, construct a key for the identification of the specimens in the collection.

iii. Collect ten highly contrasted organisms and invent scientific names that describes each as clearly as possible (a Latin dictionary will be useful for this work). Make sure the names are in the correct "two name" form used by biologists. If you can, find out from books or from a museum, the real scientific names given to the organisms. Decide which name is better for each - real name or chosen name.

iv. Collect as many animals and plants as possible from one habitat. Invent a classification system for them. Compare this scheme with the system used by biologists.

12.6 *Concept III. Living things are interdependent.*

Suggested Activities:

i. Make observations and collections of living plants and animals from one of the following places: (a) a pond or stream; (b) a pool on a rocky seashore; (c) the leaf mould on the floor of a forest. Bring your collections back to school and set them up in aqaria or vivaria. Construct a food web for the organisms that have been collected. Evidence for this should come from direct observation in field and classroom of feeding behaviour, and by deductions based on general concepts of autotrophism, hetertrophism and pyramid of numbers. Useful evidence can also come from the types of mouth-parts; general habits; locations and relative sizes of organisms.

ii. Workout the pyramid of biomass for a community living in a small isolated (perhaps stagnant) pool of a freshwater stream. Do this by collecting everything from the pool, measuring the water volume and scooping out and keeping all the organic ooze and debris. Sort the animals into: (a) herbivores; (b) detrital feeders and carnivores. Take the "dry-weight" of the organic debris; of the collection of herbivores and detrital feeders and of the carnivores. Plot a pyramid of biomass (pool should be 5 to 10 litres in volume).

iii. Collect plants and animals from a freshwater stream and set them up in an aquarium in the laboratory. "Balance" the aquarium and discuss how the animals and plants can survive in such a "closed" system.

iv. Make a survey of families living in the area of the school and by checking on their meals for a day work out a food web for the local community centred on man.

12.7 *Concept IV. Conservation of natural resources*

Suggested Activities:

i. Visit well managed and poorly managed farms and compare incidence of soil erosion; noxious weeds; over-worked soil; and over-all yields. Consider reasons for differences observed.

ii. Make a survey of the occurrence of native animals and plants in an area near the school. List these. Make a survey of knowledge and opinions of local people on the existence and value of these plants and animals. Plan a campaign for the conservation of native species.

iii. Choose a one or two mile walk in an area near the school that passes interesting communities of living things and places of natural beauty. Organise this as a "nature trial" by selecting numbered "stations" and preparing a map for walkers with notes on points of interest at each station.

iv. If it is possible to do so, visit a game park or natural history reserve. Find out details of its management and organisation and decide on its effectiveness in conserving plants and animals.

v. Choose an interesting area of natural bushland, seashore, swamp or grassland near your school or town. Pretend that it is to become a natural history reserve. Plan the objectives, development, organisation and management of this proposed reserve.

12.8 *Concept V. Man is polluting his environment.*

Suggested Activities:

i. Visit some local farms and find out which pesticides are being used by the farmer. Find out from either the farmer or from the Ministry of Agriculture which organisms absorb and store these chemical pesticides. Trace the possible pathways that such chemicals may take through a living community.

ii. Tour an area immediately surrounding the school and find how local people are disposing of garbage, litter and general household wastes. Are there central dumps? Is there evidence of general litter and untidiness? Consider the implications of your study for the health and hygiene of the community. Find out the opinions of ordinary families, of doctors and of local administrators on the problems of disposal of litter and rubbish.

iii. Visit some city factories and find out what products they make. List the raw materials needed and the wastes produced. Find out how the wastes are removed and where they go to eventually. Consider the implications of this for the environment of man.

12.9 *Concept VI. The community is responsible for its health*

Suggested Activities:

i. Make a survey of health hazards in the immediate area of the school. On a map locate places likely to be sources of infection, e.g. garbage dumps; breeding sites for locally prevalent vectors of parasitic disease; open drains; likely sources of contamination of drinking water; examples of inadequate disposal of sewage. Prepare a report with recommendations for the improvement of local hygiene.

ii. Visit a local hospital and interview officers-in-charge to discover the main types of illness of patients. Try to determine how much is due to exposure locally to infectious disease organisms.

12.10 *Concept VII. Biological principles are applied in the hygienic processing of food*

Suggested Activities:

i. Make a survey of food shops and stalls near school and assess the precautions taken to reduce possibility of contamination by disease organisms.

ii. Visit a canning factory and observe the processes of preparing and canning food. Pay special attention to the laboratory or test unit which checks on the purity of the foods. Relate to work on microbiology and disease.

iii. If there are local places where food is preserved by smoking and drying observe the processes, listing the foods involved and discussing implications for health and hygiene.

12.11 *Concept VIII. Convergence and divergence in evolution*

Suggested Activity:

i. Visit a zoo or museum, preferably the former, and study the members of one mammalian order (say the cloven-hoofed mammals). Observe how they have become different in response to living in different places, in spite of having a common ancestry. By contrast, also study the members of several mammalian orders that live in the one habitat such as grassland or freshwater. Show how they have features in common in spite of having different ancestries.

12.12 *Concept IX. The evolution of man*

Suggested Activity:

i. Visit game parks, zoos or museums to study as many as possible of lemurs, *Tarsius*, monkeys, gibbons, orang-utans, chimpanzee and *Gorilla*. Study features such as locomotion, type of chest, type of hand and foot, facial profile, relative proportions of trunk and limbs, and behaviour. Compare with man and discuss implications.

12.13 *Concept X. The components of environment determine the distribution and abundance of organisms*

Suggested Activities:

i. Make a study of the diversity, distribution and abundance of organisms in two types of agricultural fields. Choose a field that has been neglected and poorly managed and one that is productive and well managed. In each, use standard methods of collecting in standard time by a standard number of collectors. Collect animals separately from the soil, the litter layer and the crop or grass layer. Assess the chemical and physical properties of each layer in each field. Try to explain the variety and abundance of the animals of the two fields in terms of their physical and chemical environments.

ii. Using the *capture-mark-release-recapture* method assess the numbers of organisms in two contrasted place of the same unit area. Assess differences between chemical and physical characteristics of the two places and develop theories to explain differences between the populations. Studies may be of grasshoppers in well-managed and poorly-managed crops; water striders on swamps or on the surface of streams; fruit-flies in forests and in cultivated orchards; or intertidal marine snails in pools and rocks.

iii. Make estimates of the densities of weeds in well-managed and poorly-managed grazing land and relate differences to assessed differences in soils and microclimates of the two pastures.

APPENDIX

A Taxonomy of Objectives for Science Education in Secondary Schools

This system of objectives has been prepared by a sub-committee in New South Wales for the consideration of the Science Syllabus Committee of the Higher School Certificate. The objectives are currently (June 1969) being considered by the Syllabus Committee. The statement is presented here by permission of the N.S.W. Science Syllabus Committee (Higher School Certificate). It has been included for the purposes of discussion. Different countries would modify these objectives according to local needs.

AIM I. To Develop a Knowledge and Understanding of Modern Science

1.1 To develop a knowledge of modern science.
- 1.11 Knowledge of scientific facts
  - 1.111 Specific facts
    Knowledge of those specific facts needed for the development of the principles, generalisations, theories and structures of the course.
  - 1.112 Concepts
    Scientific data is reducible to a limited number of general concepts.
    - 1.1121 Principles
    - 1.1122 Generalisations
    - 1.1123 Theories
    - 1.1124 Structures
  - 1.113 Fundamentals
    Underlying the concepts used in science is the scientists' view of the fundamental nature of the universe based on ideas of:
    - 1.1131 matter and energy
    - 1.1132 space and time
    - 1.1133 motion and force
    - 1.1134 force fields
    - 1.1135 conservation of matter and energy
    - 1.1136 speed of light
    - 1.1137 quantization
- 1.12 Knowledge of the processes of science
  - 1.121 Processes of
    - 1.1211 Observation
    - 1.1212 Experiment
    - 1.1213 Suggesting hypotheses
    - 1.1214 Definition
    - 1.1215 Propounding theories
    - 1.1216 Discovering laws

    which make use of
  - 1.122
    - 1.1221 Conventions (e.g. symbols)
    - 1.1222 Trends and sequences (e.g. activities series)

1.1223 Classification (e.g. classification of rocks)
1.1224 Criteria (e.g. properties of minerals)

1.13 Knowledge of the impact of science on man and his culture
(Note: the further and detailed expansion of the headings of the sections of 1.11 will provide the subject matter content of the course).

1.2 To develop an understanding of modern science.
The understanding of modern science is to be developed in terms of the knowledge specified in 1.1 and involves the intellectual abilities and skills set out below.

1.21 Comprehension - the ability to deal with information by expressing it in other forms, by interpreting its meaning and by making predictions based on it.
1.22 Application - the ability to select and use scientific knowledge to provide a solution to a problem situation.
1.23 Analysis - the ability to identify the parts of a situation, to recognise the way in which the parts are related and to identify the principle or principles in the relationship.
1.24 Synthesis - the ability to organise information from various sources to bring out new relationships.
1.25 Evaluation - the ability to judge the scientific worth of ideas, objects and methods.

AIM 2. To Maintain and Develop Interest in Science and to Develop a Scientific Attitude

2.1 Interest in Science
Development of interests in
2.11 the methods of scientists
2.12 the facts of science
2.13 the application of science to
2.131 personal problems
2.132 community problems
2.133 national problems
2.134 international problems

2.2 Attitudes
2.21 To develop a scientific attitude involving:
2.211 a lively curiosity
2.212 a willingness to adopt a systematic and careful approach to investigation
2.213 the deliberate suspension of judgment
2.214 a willingness to be convinced by evidence
2.215 a willingness to consider new ideas
2.216 a tendency to consider statements critically
2.217 desire to pursue an independent line of study

2.22 To develop worthwhile attitudes to science, particularly:
- 2.221 an appreciation of science as a method of inquiry
- 2.222 an appreciation of scientists and their work
- 2.223 an appreciation of the limitations of science and scientists
- 2.224 an appreciation of the intellectual satisfaction to be gained from studying science
- 2.225 an appreciation of the role of science in conserving natural resources.

AIM 3. To Develop Skills in Making and Recording Observations

3.1 Direct observations using the unaided senses
- 3.11 hearing
- 3.12 sight
- 3.13 tough
- 3.14 taste
- 3.15 smell
- 3.16 nerve-muscle senses, e.g. experiencing forces

3.2 Observations involving the manipulation of scientific equipment to
- 3.201 measure quantities such as
  - mass
  - length
  - volume
  - time intervals
  - forces
- 3.202 count events
- 3.203 read scales
- 3.204 make observations using optical instruments
- 3.205 wire a circuit
- 3.206 use sources of heat and electricity
- 3.207 handle chemicals
- 3.208 separate substances
- 3.209 determine properties using indicators
- 3.210 carry out field work
- 3.211 carry out dissections
- 3.212 handle living things
- 3.213 determine special properties of rocks and minerals

3.3 Recording of data by means of
- 3.31 well organised writing
- 3.32 tables
- 3.33 graphs
- 3.34 labelled outline diagrams
- 3.35 photographs
- 3.36 charts from automatic recorders

AIM 4. To Develop the Skills of Communicating to Others the Knowledge, Understanding, Interests and Attitudes and the Skills in Making and Recording Observations Gained in the Course

4.1 Writing
- 4.11 reports
- 4.12 summaries
- 4.13 plans

4.2 Speaking
- 4.21 answering questions
- 4.22 lecturettes
- 4.23 symposia
- 4.24 group discussions
- 4.25 teaching others
- 4.26 making tape recordings

4.3 Graphic means
- 4.31 outline diagrams
- 4.32 drawings
- 4.33 still and movie photographs
- 4.34 displayboards
- 4.35 models
- 4.36 demonstrating equipment

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