Integrated science in the junior secondary school in Sri Lanka

by A. M. Ranaweera
EXPERIMENTS AND INNOVATIONS IN EDUCATION

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Integrated science in the junior secondary school in Sri Lanka

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Study prepared for the Asian Centre of Educational Innovation for Development

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Preface

In 1972 Sri Lanka initiated a major reform of its education system. A series of six studies, of which the present publication is one, describe the different aspects of education and how they were affected by the educational reform: in some aspects totally new programmes, designed and developed ground-up, were introduced; in others, the current programmes were reoriented, with new emphases and focal points.

The reform occurred in an education system which for quite a few decades had come to be taken for granted because of its steady rhythm of expansion and growth. As the present series of studies show, the driving force of the reform came from outside the education system, and lay in the urgencies of the social and economic situation. The changes triggered off in consequence within the education system are both comprehensive and fundamental, and serve to illustrate how the processes of reform and innovation are interlinked.

In the 1960s, many countries in Asia including Sri Lanka initiated quite extensive programmes in reforming science education. In Sri Lanka the new science education programmes were directed to the upper grades of the secondary stage. The Educational Reforms of 1972 made an important departure from this policy by shifting the emphasis to the lower grades where the largest number of pupils are.

The present study gives a comprehensive background information on the science curriculum development from 1957 until the present day. Following the 1972 reforms, science became an important subject in the general education curriculum for grades 6 to 9 and took the form of integrated science.

The Secretariat, while noting that the views expressed by the author are not necessarily those of Unesco, records its appreciation to him for this valuable contribution to the series.

The others are:
Ariyadasa, K.D. In-service training of teachers in Sri Lanka.
Premaratne, B. Examination reforms in Sri Lanka.
Diyasena, W. Pre-vocational education in Sri Lanka.
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I. INTRODUCTION

Survey of science curriculum development programme 1957 — 1972

The second half of the 20th century brought a great concern and urge to rethink school curricula both in the developed and developing worlds. The momentous educational changes taking place throughout the world were an expression of the desire to provide better living conditions for all through modern scientific and technological achievements. In Sri Lanka this concern for changes in education and for a break-down in the disparity in educational facilities available to different economic, social and ability striations of the community manifested itself in many ways. One major manifestation was the science curriculum development programme initiated in 1957.

The curriculum development programme was spearheaded through science education because it was assumed that science and technology were the prime contributors to the highly accelerated changes taking place in the social, economic and cultural fields today, particularly in developing countries. The designers of science curricula have the great responsibility of acting as social engineers endeavouring to rebuild the social landscape and moulding the future generation to fit effectively, creatively and responsibly to the future world. Sri Lanka, as a developing country, has to look mainly to science education to provide the manpower and technical expertise needed for rapid development.

In this context the Ceylon Science Curriculum Development Programme was launched, and it took into consideration three major factors affecting science education:
1. The rapid increase in school enrolment and in the characteristics of the pupil population;
2. The advances made in the field of learning theory and educational psychology which made a significant contribution to classroom teaching methodology;
3. The enormous increase in the content of science and the significant changes in the structure of science disciplines.

The rapid changes in social values regarding education, the expansion of educational facilities to benefit underdeveloped regions and depressed social strata in Sri Lanka, the changes in society's utilization of individuals with secondary educa-
tion, the perceptible rise in living standards, and many other factors, caused a rapid increase in the rate of school enrolment, especially in the sciences.

There was cause for concern regarding the content and methodology of science teaching. For 95 per cent of the pupils enrolling for science, the G.C.E. (Ordinary Level) examination at the end of grade 10 was the terminal course in science. Only about 5 per cent of the total science students had some chance of utilizing their science learning at higher levels. It was realized that the academic, didactic, bookish teaching tradition considered to be suitable for the 5 per cent was hopelessly inadequate for the 95 per cent of the less able pupils. Even for the more able of the G.C.E. (Ordinary Level) population, the didactic chalk-talk methodology was inadequate for achieving the objectives of science education.

Changes in the composition and aspirations of the G.C.E. (Ordinary Level) population demanded changes in the educational objectives hitherto assumed. As national and social needs change, education systems must review their goals and take necessary steps to provide a service to the community in a manner that is valid in terms of new or emerging cultures, national development patterns and contemporary thought. In this context questions such as the following needed to be asked:

i. Were we teaching science in our schools?
ii. Were we teaching science that was suitable to our children?
iii. Was the teaching also concerned with the way scientists obtain scientific knowledge (process of science)?
iv. Was the teaching concerned only with the body of scientific knowledge (product of science)?
v. Were we concerned with skills and attitudes as well?
vi. Were we using proper methods consistent with current knowledge of the learning process?
vii. Were we assessing science learning suitably?
viii. Were we teaching in such a way that the system could readily adopt desirable changes, leading to efficiency and economy?

The answers to these questions clearly indicated the need for a revision.

Formulation of objectives

In setting specific objectives for a new curriculum, the designers realized that a clear understanding of the dimensions of pupil growth, particularly in science education in Sri Lanka, was essential. This involved consideration of:

- Cognitive domain (knowledge frameworks, applications and uses of same)
- Psycho-motor domain (skills of specified types)
- Affective domain (attitudes and value frameworks)

It was recognized that objectives should be based on the following factors:

The Sri Lanka child
(his present attitudes, goals, abilities, knowledge, skills, interests, needs)
ii. The Sri Lanka society
   (its hopes and aspirations, its opportunities, its demands and defects)
iii. The contribution science can make to the education of the child.
iv. The process by which children learn
   (theory and practice of learning)

From among the several significant analyses available for the cognitive domain, that of Bloom\(^1\) was used by the designers.

**Operational principles and criteria for revision programme**

It was necessary to derive certain working principles and criteria to guide the designers of the new curriculum.

These working principles and criteria were derived from:

i. Current situation with regard to human, material and time resources;
ii. Existing pattern of examinations;
iii. Current theories of learning.

**Resource data**

In developing a new curriculum, it was realized that decisions pertaining to content, method and depth of treatment, pupil and teacher activities and experiments, and a host of other constituents had to be based on the quality and quantity of resources available. This necessitated a gathering of essential data related to human resources, material resources and time as a resource.

**Examination data**

The designers recognized that the data extractable from the examinations held at this level were shaped by characteristics of the educational environment of many years. The data reflected the status of education, its objectives, and the achievements of pupils working towards those objectives. The analyses of the content and objectives of the G.C.E. (Ordinary Level) examination revealed that all was not well with science education. A heavy bias in favour of mere factual recall was evident. It was not surprising, therefore, that the teaching, geared to the examination, also emphasized the recall of factual information.

**Current theories of learning**

In addition to opinions about the manner in which children learn, voiced by experienced teachers, a detailed consideration was made of current thought in the field of learning and teaching. In this context, the following analyses were made: process

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1. Bloom, Benjamin S. (Editor) *Taxonomy of Educational Objectives*, N.Y., Longmans Green (1956)
of concept formation; theories of learning; transfer of learning; motivation in learning; attitudes; and learning motor skills. Some working principles were then derived to guide the designers of the new curriculum.

Science curriculum development projects 1957 — 1972

When the Science Curriculum Development Programme was first planned in 1957, a survey of the situation indicated three levels of science teaching that needed attention:

Level I: 6; 7 and 8 standard level (11+ to 14+ age group)

In the middle school grades, general science was being introduced for the first time as a subject. (In a few large schools general science had been taught for over a decade).

Level II: 9, 10 standard or G.C.E. (Ordinary Level) (14+ to 16+ age group)

The G.C.E. (Ordinary Level) classes in science were available in a few relatively large schools at the time. There was a fairly long tradition of science teaching, but the approach adopted was determined by the objective of preparing pupils for examinations. At this level no details of instructions were prescribed by the Department of Education, except in terms of examination syllabuses. These examination syllabuses had been modelled on the London Matriculation and the Senior Cambridge Examinations. In consonance with the recognized examination objectives, the teaching methodology was largely didactic, with certain demonstrations or activities used only to verify the principles and facts taught.

Level III: 11, 12 standard or the H.S.C./G.C.E. (Advanced Level) (16+ to 19+ age group)

Here the situation was similar to that in Level II but, in addition, practical work of a stereotyped nature was performed by pupils. This work was regarded more as practice for the practical examination at the end of the two years than as a base of experience for learning the concepts of science. The university requirements had a great influence at this level and it was recognized that development here should be planned in close collaboration with the university authorities.

Development of science education (1957 — 1973)

The quantitative development of science education may be inferred from the following figures:
a. No. of schools teaching science up to G.C.E. (Ordinary Level)

<table>
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<tbody>
<tr>
<td>No. of schools:</td>
<td>18</td>
<td>52</td>
<td>115</td>
<td>125</td>
<td>540</td>
<td>800</td>
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b. G.C.E. (Ordinary Level) Science — No. of candidates

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<tbody>
<tr>
<td>No. of candidates:</td>
<td>6,000</td>
<td>10,000</td>
<td>31,000</td>
<td>54,000</td>
<td>88,000</td>
<td>129,000</td>
</tr>
</tbody>
</table>

c. No. of schools teaching science up to G.C.E. (Advanced Level)

<table>
<thead>
<tr>
<th>Year</th>
<th>1957</th>
<th>1967</th>
<th>1973</th>
<th>1974</th>
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<tbody>
<tr>
<td>No. of schools:</td>
<td>50</td>
<td>146</td>
<td>198</td>
<td>225</td>
</tr>
</tbody>
</table>

d. G.C.E. (Advanced Level) Science — No. of candidates

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<tbody>
<tr>
<td>No. of candidates</td>
<td>1,500</td>
<td>5,800</td>
<td>7,000</td>
<td>12,600</td>
<td>14,700</td>
</tr>
</tbody>
</table>

e. Provision for science equipment (in rupees)

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<tbody>
<tr>
<td>Rs.</td>
<td>109,000</td>
<td>1,800,000</td>
<td>3,500,000</td>
<td>4,600,000</td>
<td>4,800,000</td>
<td>9,400,000</td>
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</tbody>
</table>

Note: In 1971, general science was taught in grades 6, 7, 8 in about 1,000 schools.

In 1972, integrated science was introduced to grade 6 in about 6,200 schools.

Science curriculum development work in Sri Lanka may be traced back to 1957 when a General Science Project for grades 6, 7, 8 was initiated. A syllabus of instruction and schemes of work for teachers were published and made available to teachers. This general science course was meant to be an essential component of general education for all pupils at the grade 6, 7, 8 levels.

The second phase of the curriculum development activity commenced in 1961 with a major revision of the grades 9 and 10 (G.C.E. Ordinary Level) curriculum in chemistry, physics and biology. During the years 1961 — 1963, detailed syllabuses of instruction and schemes of work for teachers were prepared in the above subjects. This exercise was an attempt to adapt to the changed circumstances so that the new emergent needs of pupils could be better met within the constraints of human, material and time resources. Certain major changes were also affected in the G.C.E.
(Ordinary Level) examination in 1965, by the introduction of more valid and reliable techniques of evaluation.

Even though major curriculum changes were not introduced at that point of time at the G.C.E. (Advanced Level), certain attempts were made to make the Advanced Level teachers conscious of new trends in teaching science at that level. Major changes were, in fact, made in the design and structure of the Advanced Level examination in science subjects with effect from 1971. During this period the accent in curriculum development was on quality improvement and the extension of science education.

**Development since 1972 — Introduction of the new educational scheme**

The Ministry of Education ushered in certain major changes in the educational structure of the country through the new educational scheme introduced in 1971. Under this new scheme curriculum development work has been organized at three levels:

(a) Primary (grades 1-5, Age 6-10);
(b) Junior Secondary (grades 6-9, Age 11-14);
(c) Senior Secondary (grades 10-11, Age 15-16)

In introducing new educational reforms the Ministry announced:

"During the last decade educational planners in Sri Lanka have concentrated mostly on the expansion of science and technical education, and quality improvement in secondary education, through curriculum development, in-service training and evaluation. Nobody would question the educational validity of this strategy. However, with increasing unemployment among the educated youth, even among the technically qualified and Tamil medium science graduates, one has to raise the question whether a strategy of quality improvement and extension of science and technical education as presently conceived, by itself will deliver the goods."

Education exerts such an influence on society that all sections interested in social reforms and economic development give increasing attention to educational objectives. Education has a multifunctional role to play in a developing society. Demands on education never remain static in a dynamic society and the adaptability of an education system is reflected in its response to emerging needs. Determination of priorities in education in the context of the prevailing socio-political climate and reconciliation of educational priorities with economic imperatives are essential to harmonious growth of the education system.

The broad objectives of the new curricula introduced in 1972 have been stated as follows:

(a) Working towards a better 'fit' between the education system and economic needs of the country. This has to be done without violating the broader objectives of education.
(b) Achieving greater internal quality and effectiveness within the education system.

(c) Furthering equality of access to education
   (i) by reducing regional imbalances in the provision of education facilities; and
   (ii) by effecting changes in the structure of the school system with a view to removing the disabilities suffered by some pupils.

The new policy on science education is based on the above broad aims.
II. INTRODUCING INTEGRATED SCIENCE

Science at the junior secondary school level (grades 6-9)

One of the most important features of the educational reforms introduced by the United Front Government in 1971 was making science a compulsory subject in the general education curriculum for the junior secondary school grades 6 to 9. That science education should be a compulsory component in a general education programme geared to national development has been universally recognized and is seen in policy papers such as An Asian Model of Educational Development: Perspectives for 1965-1980 where it is stated that:

"... it is the application of science and technology that has made it possible for the advanced countries of the world to banish poverty and provide a high standard of living. A similar scientific and technological revolution would have to be brought about in Asia if a new social order that would provide abundant life for all is to be created."

The above Report states the broad working principles for a science education programme in the following terms:

"Science education has a strategic role in the process of adapting education to the needs of rapid social and economic change. Science is not only a body of knowledge; it is a way of thinking and doing, of looking at things and events, an introduction to 'learning how to learn' and as such teaching of science and mathematics is a powerful means for developing the attitude of critical inquiry, adaptability and the habit of systematic and hard work which underlie the process of change."

In implementing the 'science for all' policy of the Government, the Ministry introduced a new integrated science programme for the junior secondary school. This new programme has been designed to serve two purposes. Firstly, science is considered as a cultural and educational discipline cultivating in pupils an understanding of the phenomena of nature and the scientific mode of apprehending them. Science in this respect is considered an essential component of general education and should form an integral part of the general education of all the nation's children. Secondly, science education must serve to produce future scientists and technical workers by
training pupils to understand the fundamental principles which govern scientific and technical activities.

**Why integrated science?**

While accepting the principle that science should be a compulsory subject at the junior secondary level and should be taught as an essential component of general education, it was thought that the best way to achieve this aim was to teach science not in the form of physics, chemistry and biology but as a combined, integrated course.

During the last few years, there has appeared to be an increasing interest in integrated science. Integrated science as it is understood today is not the traditional 'general science' that was taught at middle school level in most countries. Those general science courses failed to fulfil the wider objectives of science teaching as a part of general education. One major shortcoming of such courses was the emphasis on content and neglect of method which resulted in the courses being taught in three parts corresponding to chemistry, physics and biology with no indications of the unifying themes and concepts of science. This led to a superficial treatment of a few popular topics in physics, chemistry and biology without achieving the aims of teaching science.

There are several advantages in teaching science as an integrated subject:

(a) From a philosophical standpoint it is evident that there is *unity* in the purpose, content and activities of science. The *processes* involved in science are common to all branches of science. Only an integrated course will establish in the student's mind an appreciation of the unity of science.

(b) Integrated science has educational advantages from the standpoint of teaching and learning. An important aspect of curriculum organization is to concentrate learning experiences and structure them as much as possible to obtain maximum cumulative effect. This concentration and structuring of learning experiences is made feasible by bringing the content of several courses together into a coherent whole.

(c) Integration is also vital considering the increase and diversification of knowledge. The pursuit of knowledge becomes increasingly difficult as knowledge advances and as the number of specialized fields increases. Science, treated as an integrated subject, will enable the pupils to grasp its *patterns* and *generalizations* which will form a sound basis for later specialization and study in depth.

(d) Logical content development and prevention of overlapping is also possible through integration. This makes teaching and learning more economical and efficient.
An integrated approach will increase the breadth of student participation in a variety of science fields.

Integrated science eliminates the ill effects of early specialization. When pupils are expected to study several science subjects from an early age, they get little formal education outside their specialities. Hence it is not surprising that they leave school with little knowledge of, or interest in, the problems of the society. It is hoped that through integrated science, all pupils will be able to study a balanced course in science and also find the time to take an interest in social problems, arts and humanities.

Objectives of the integrated science course

The major objectives of the four-year science course are listed below. The syllabus content is directed to these objectives. While the syllabus and the teachers' guides indicate an organization of the selected content and preferred methods of instruction, teachers are at liberty to organize and instruct differently provided the major objectives are achieved. The objectives are not intended to be achieved consecutively. They are not steps leading to a summit. They are different aspects of what the science course is intended to achieve over the four-year period. A particular lesson may emphasize one aspect to the exclusion of the others. But over a period of time each aspect should be met, not once but many times, each time the understanding being taken a little further.

Pupils completing the course should be able to do the following:

i. Welcome the findings of science as adding to the stock of human knowledge:

Pupils should become aware that there is a body of knowledge called science. They should be keenly aware that this is a very rapidly expanding body of knowledge. While in general they are not expected to consider philosophical questions about what science is, they should realise that it is different from other areas of knowledge such as mathematics, language, religion, etc. Pupils should be aware of some of the very significant ways in which science has enriched man's knowledge. They should be made aware of some instances where scientific knowledge was used to cause considerable suffering for the human race. However, it is not difficult to find sufficient examples to develop the attitude that findings of science should be welcome.

ii. Support scientific activity:

If the findings of science are welcome as having generally been of benefit to mankind, there is need to support scientific activity. There was a time when this activity was largely the work of individuals. But current activity demands heavier investments and team work. The problems to be investigated are no longer
matters of individual interest but problems derived from national policy. For the majority of our future citizens this course is their only formal study of science. Pupils should be made aware of research institutes such as the Central Agricultural Research Station at Gannoruwa, the T.R.I., the R.R.I., the C.R.I., the Ceylon Institute of Scientific and Industrial Research and the Research Departments of the Universities. The role of these institutes and the significance of their work for national development should be made known. The continuation and expansion of such activity is essential.

iii. Know the situations which demand the help of scientists and seek such help:

Very few pupils will continue their study of science to acquire sufficient proficiency to solve many problems by themselves, even assuming that they have the other resources. Nevertheless, it is desirable to develop in them the capacity to recognize the problems which may be answered through the application of science. If there is a crop disease, is it better to have the farmers praying for the help of the supernatural than seeking the advice of scientific personnel? Is a chronic illness due to the ‘evil eye’ or to some natural cause? Can the coconut husk be soaked in pits without at the same time breeding mosquitoes or producing foul smells? Some problems may require sophisticated research to provide an answer. Indeed some may not be answerable in the current state of knowledge. For some, solutions may already be available. But in all cases it is very desirable that the problem be recognized and that pupils know the sources from which help can be obtained.

iv. Attempt to solve some problems in the manner that a scientist would:

Pupils should have first-hand experience of the way in which a problem situation is tackled by a scientist. If the course were to provide a sufficient number of such instances, and pupils were helped to generalize their experiences it could be expected that on their own they may attempt to use at least a part of the sequence of activities generally regarded as constituting the scientific method. The personal lives of pupils may provide many instances where such behaviour would be beneficial. The tendency to believe that if event A is succeeded by event B then A is the cause of B may account for the continued prevalence of superstitious beliefs. It may also prevent further investigation. The objective described under (iii) above referred to situations which could be of public interest. The objective described here refers more to the private and social life of the individual.

v. Be sensitive to situations which demand further investigations:

Pupils should be inquisitive about their physical and biological environment. By
nature most children are inquisitive; what is required is to maintain this throughout the secondary school and into adult life. Something unusual may draw the attention of a pupil and he should pause to make further investigations. It may be the peculiar behaviour of an animal, an unusual weed found in the vegetable plot, a diseased plant, etc. Many may pass them by, but at least some should pause to wonder.

vi. Comprehend the major unifying science concepts and patterns:

Objective 1 above referred to the need for pupils to be aware of the body of knowledge called science. This awareness must be the result of studying carefully selected portions of it. Although the body of knowledge is vast, certain fundamental concepts have been used to organize the knowledge. The science course should enable pupils to comprehend the major unifying science concepts and patterns. Among these would be such concepts as energy, evolution, momentum, element, chemical change system. The principle of conservation of energy, the structure of matter, the law of gravitation are among the 'patterns' that pupils should comprehend.

vii. Understand fundamental science concepts sufficient to:

(a) accept scientific explanations of common natural phenomena;
(b) comprehend general scientific advice in relation to such areas as personal health, agricultural practices, public health, etc.;
(c) comprehend references to scientific matters in mass media;
(d) appreciate the need to conserve national resources;
(e) apply it (where simple applications are possible) to the production processes of vocations practised in the community.

The bulk of the teaching under the course would be to achieve this objective. The achievement of the other objectives depends on this. The community at large will not be composed of research scientists, but it should be composed of people who can do what is stated in objective (vii) above. For example, people should be aware of the factors which lead to rain, the rainfall patterns in their area and that man's activity can well affect the rainfall patterns. Traditional rites should be examined from such a perspective. Social pressures against harmful practices such as fish-dynamiting have to be built up on the firm basis of adequate scientific knowledge. Knowledge of the scientific basis of traditional craft practices can lead to their improvement.

viii. (a) Use simple measuring instruments and observational aids:
(b) **Record observations**
(c) **Carry out simple experiments**

The four-year course must provide opportunities for pupils to use measuring instruments such as thermometers, voltmeters and ammeters and observational aids such as a simple microscope. An important aspect of the scientific method is that observations made by one person are in general capable of being obtained by another. Hence the need to record observations so that they are examinable by others and the potential for replication exists. Experiments that pupils will be called upon to do may extend over long periods and may have to be conducted outside the laboratory. For example, pupils might investigate whether the presence of salt water in the soaking pits for coconut husks affects the colour of the fibre. The classroom instruction might develop the knowledge and skill required to carry out such a study.

**Outline of four-year course**

In drawing up the integrated science course for the junior secondary school, some effort was made to relate it to the local environment and to make the material and experiences relevant to everyday life. One of the main objectives of a school science course should be to help future citizens to participate actively in the economic development of the nation. In this context, since a large percentage (about 80% — 85%) of the population in Sri Lanka live in villages and are dependent mainly on an agrarian economy, science education should make a contribution to the improvement of agricultural practices and agro-based industries. The teaching schemes should provide knowledge and skills relevant to agriculture and create healthy attitudes towards agriculture as a vocation. The science course should also take note of the natural resources of the country and their use in industrial development.

With these objectives in mind, the science schemes, together with the pre-vocational courses, are geared to the environment, natural resources and the vocations practised in the community.¹

The following is an outline of the content of the four-year course. However, this outline does not reflect the nature and flavour of the learning experiences and activities envisaged in the course.

**6th grade**

1. **Preliminary study of the physical and biological environment of the school and the home**

   Living and non-living things — living things can be either plants or animals. Observation of behaviour of living things. Properties such as hardness, texture, colour, etc. Observation of the diversity and richness of materials and organisms

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¹ Refer published in this series, Dryasena, W, *Pre-vocational education in Sri Lanka.*
in the immediate neighbourhood. Simple groupings of materials. Awareness of heat, light, sound, electricity and some of the common sources from which they are obtained. Skill in using the thermometer.

2. **External characteristics of living things in the school and home environment**

   External features of animals. Their classification into appropriate categories. Awareness of common features and functions such as sense organs, organs for moving about, intake of food, excretion of waste matter, reproduction.

   External features of plants. Their classification into appropriate categories. Awareness of common features and functions such as roots, stem, branches, flowers, reproduction, intake of water through root system. Food chains (in the living world).

3. **Looking at the soil**

   Simple analysis of the soil-gravel, sand, clay, humus. Presence of air, water, organisms. Soil types and their ability to retain air and water. Importance of soil in agriculture. Some factors leading to soil erosion. Soil conservation.

4. **Changes in materials and some agents of change**

   Heating, dissolving, crushing and burning a variety of common materials such as paper, wood, candle, sugar, flour, camphor, salt, rock, leaves or vegetable matter, cloth, plastic, etc. to effect changes. Some useful changes and agents for effecting them. Obtaining common salt from sea-water. Purification of crude common salt. Water cycle in nature, uses of water, solutions, distillation of water.

5. **Changes in nature**

   Making systematic observation and maintaining records about changes taking place in the environment. e.g. room temperature, rainfall, information about winds and clouds, shape of the moon. Changes taking place in the animal and plant world. Seasonal agricultural and industrial activities. (This will be a continuing activity throughout the course)

6. **Building-blocks of nature**

   Elementary notion of the nature and size of different building blocks in the universe: sun, planets, communities, populations, organisms, cells, particles (atoms, molecules).
7. **Plant breeding — Food supply**

Different methods of vegetative propagation using stems, roots, leaves, methods of budding and grafting. Germination of seeds, conditions for germination.

Dispersal of seeds.

Some factors that influence growth of plants. Types of food, balanced diet, preservation of food.

8. **Heat as an agent of change**

Some effects of heating substances in air, mainly, expansion, change of state, formation of new substances.

Heating of metals in air, active component of air (oxygen); inactive component of air (nitrogen).

Burning of a candle and other common substances: fuels, products of combustion; tests for carbon dioxide.

Degree of heating; measurement of temperature; thermometers.


9. **Some effects of radiation from the sun**


Observation of evaporation, bleaching action, expansion, photo-chemical actions. Effect of sunlight on plant and animal behaviour. Necessity of sunlight for plants and animals.

10. **Movement and forces**

Idea of force introduced as pushing, pulling, lifting, stretching, compressing, etc. Forces of repulsion and attraction between magnets. Study of patterns of stretching. Weight as a force. Some methods of producing forces such as compressed steam, compressed air, draft animals. Levers.

11. **Some useful materials from the earth**

Formation of soils by weathering and action of organisms. Types of rocks.
Useful material like plumbago, mica, iron, copper, tin, limestone, gems, etc. Study of simple properties and some uses.

7th grade

1. *Interactions between substances*


2. *Digestion and absorption of food*

   Digestion in terms of increased solubility of end product units necessary for synthesis. Carbohydrates, fats, proteins in balanced diet with reference to energy supply and growth. Types of food and their sources.

3. *Devices to make work easier*

   Devices to change point of application and direction of forces. Equilibrium of forces. Inclined plane, pulleys, wheel and axle, levers. Measurement of load and effort. Study of simple lever systems in animals. Applications of simple machines in the home and in the environment.

4. *Building blocks of nature — II*

   Elements. Some common elements and their properties — iron, aluminium, lead, copper, zinc, silver, gold, carbon, mercury, sulphur, oxygen, hydrogen, nitrogen, etc. Density. Classification into metals and non-metals. The atom as the building block of elements.

5. *Sources and flow of electricity*


6. *Further study of propagation of light*

8th grade

1. **Liquid and gas pressure**


2. **Absorption and transport in animals**

   Solubility. Factors affecting solubility: types of substance, size of particle, temperature, type of solvent.

   Absorption of end products of digestion. Circulatory system — the need for a circulatory system; structure and working of the mammalian heart; the anatomy of arteries, veins and capillaries; the functions of blood cells and plasma; the origins and functions of lymph and body fluid. The human heart as a machine.

3. **Work and energy**

   Definition of work in (gravitational units). Potential and kinetic energy. Efficiency of simple machines. Frictional forces. Motors and engines as converting electric and heat energy to mechanical energy. Work done by energy from the sun in relation to water cycle. Animals doing work. Work done by chemical changes.

4. **Formation of new substances**

   Relative weights of atoms, gram-atoms. Looking at changes quantitatively, molecules, chemical composition (stoichiometry), formation of new substances, chemical change.

   Some chemical changes in organisms, associated with the release of energy. The structure of the respiratory system and the mechanism of breathing.

   The transport of gases by the circulatory system, cellular respiration and the role of oxygen in respiration. Oxygen debt. The transformation of energy in respiration.

5. **Building blocks of nature — III**

6. **Elimination of waste in organisms**

Necessity of eliminating the by-products of metabolism to maintain the equilibrium of the internal environment. Conversion of amino acids to urea. The structure and working of mammalian kidney. Osmo-regulation of organisms on lands in fresh-water and in sea-water.

7. **Optical instruments**


8. **Patterns and generalizations**

Classification of properties of elements leading to concept of periodicity. Use of patterns and generalizations for organizing experiences and directing inquiries.

**9th grade**

1. **Force and motion**


2. **Production of food in plants**


3. **Building blocks of nature — IV**


4. **Elementary energy**

5. **Changes and factors which affect change**

Rate of change illustrated from different fields, e.g. velocity, growth, rusting, population growth. Factors affecting rate of chemical changes.

Applications of above principles to chemical industry, food preservations.

6. **Co-ordination and behaviour**

The structure of the ear. Production and transmission of sound. Musical notes.

Responses in an organism to changes in the external or internal environment. The structure and function of the receptors in a mammal — eye, nose, skin and tongue.

An elementary study of the general plan and the working of the mammalian nervous system reflexes. The role of hormones in the coordination and regulation of functions in animals and plants; use of hormones in agriculture.

7. **Continuity of life**

Cells and living things. Role of cells in reproduction. Asexual and sexual modes of reproduction. External and internal fertilization in animals. Development of the embryo. Pollination, fertilization and development in plants. Variations and the tendency for variations to be inherited. Chemical evolution and biological evolution, breeding of better plants and animals.

8. **Interdependence of organisms**

The ecology of a community and the variety of relationships between the organisms in a community; parasitism, predatism, competition and symbiosis. The harmful effects of some micro-organisms. Prevention and control of diseases caused by them. Transmission of infections and defences of the body against them. Weeds and pests and methods of controlling them. Useful microorganism in agriculture and industry. The food webs and the cycles of matter and energy to illustrate the interdependence of organisms.

9. **Cycles in nature**

Interaction between a system and its environment. Energy changes.

Conservation of energy. Energy cycle, useful energy, energy waste. Disorder. Influence of man on the environment and his responsibilities to society and to the biological world.

It may be noted that links with agriculture, local resources and industry are
made in the above scheme of studies through themes such as the following: looking at the soil, plant breeding, production of food in plants, interdependence of organisms, changes in nature, useful materials from the earth, changes and factors which affect change.

The units are arranged in such a way that during the early stages the pupils make observations, gather information and process it to develop the basic concepts and principles of science. In the later stages, the patterns and generalizations of science begin to emerge from a mass of factual data, concepts and principles. The teaching methodology involves activities designed to bring about an awareness of the process and method of science while providing some competencies in solving real-life problems.
III. METHODS OF OPERATION

Developing curriculum materials

A committee was set up in September 1971 to design and develop curriculum materials according to the new specifications laid down for teaching science as an integrated subject to all the children. This integrated science curriculum committee consisted of the following categories of personnel:

i. Practising science teachers who had considerable experience in teaching science at the junior secondary level in various parts of the island, especially in rural areas;

ii. Teachers who had considerable experience in science curriculum development work and who possessed a good knowledge of integrated science and chemistry, physics, biology curricula developed in other countries;

iii. Senior Ministry officials (e.g. Directors of Education and Education Officers) who had specialized in science curriculum development.

The teachers were specially handpicked on the basis of excellent performances as classroom teachers. They were seconded to the Curriculum Development Centre for the duration of the project (1971 — 1974). The leader of the group was an experienced secondary trained teacher. The committee began its task by studying the policy decisions embodied in the new educational reforms and their implications to science education. It also considered the human, material and time resources available for implementing the proposed science education programme. On that basis, the general objectives of the course were formulated.

The committee did a critical study of modern trends and curriculum material from several other countries to identify:

i. criteria for content selection;

ii. criteria for content ordering;

iii. principles of developing instructional sequences; and

iv. instructional techniques that could be adapted.
Curricula from other lands available for study at this stage included the following:

i. Nuffield Secondary Science (United Kingdom);
ii. Scottish Integrated Science (United Kingdom);
iii. Schools Council Integrated Science Project (United Kingdom);
iv. Science Curriculum Improvement Study — University of California, Berkeley (United States of America);
v. Science 5/13 (United Kingdom);
vi. Australian Science Education Project.

After a brief survey of the above material, the course content was outlined in the form of a four-year syllabus of instruction.

The next stage of the operation was to produce a teachers' guide to help the teacher plan his classroom lesson. This teachers' guide indicated a 'suggested teaching sequence' but did not lay down a rigid procedure from which the teacher could not deviate. The teacher was expected to modify the content and select learning experiences to suit the environment and needs of the children in a given school, provided that the general objectives were achieved.

To develop the teachers' guide, the four-year content syllabus was broken down to units of instruction, each of which was further divided into sub-units to facilitate teaching. Specific objectives were stated for each unit and each sub-unit. Learning experiences were briefly indicated in terms of pupil activities, teacher demonstrations and applications in everyday life.

Each unit was discussed and reviewed by the entire committee. Then one or two members were assigned to work out the activity details and to write it up. The final editing of the units was done by the entire committee. Artists were employed to draw the illustrations and the members of the committee, with assistance from the artists, prepared the final printer's copy. The material was printed at the Government Press and was distributed free to all schools by the School Organization Division of the Ministry of Education.

Almost simultaneously with the preparation of teachers' guides, the same team began to write pupils' textbooks for the new course. Those responsible for developing the units in the teachers' guide were entrusted with the task of writing the corresponding chapters in the textbook. However, the committee as a whole discussed and reviewed each draft chapter. The pupils' texts were printed at the Government Press or the State Printing Corporation and were distributed for sale through booksellers.
1. Syllabuses of Instruction and Teachers’ Guides

The material published for the entire course in the two national languages, Sinhala and Tamil, are as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>No. of pages and size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 5</td>
<td></td>
</tr>
<tr>
<td>Grade 6</td>
<td>63 (17 cm x 21 cm)</td>
</tr>
<tr>
<td>Grade 6</td>
<td>65 (17 cm x 21 cm)</td>
</tr>
<tr>
<td>Grade 6</td>
<td>87 (17 cm x 21 cm)</td>
</tr>
<tr>
<td>Grade 7</td>
<td>86 (17 cm x 21 cm)</td>
</tr>
<tr>
<td>Grade 7</td>
<td>99 (21 cm x 27 cm)</td>
</tr>
<tr>
<td>Grade 8</td>
<td>104 (21 cm x 27 cm)</td>
</tr>
<tr>
<td>Grade 9</td>
<td>150 (21 cm x 27 cm)</td>
</tr>
</tbody>
</table>

2. Pupil textbooks

The following pupil’s textbooks were also published in Sinhala and Tamil.

<table>
<thead>
<tr>
<th>Grade</th>
<th>No. of pages and size (Sinhala Edition)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science — Grade 6</td>
<td>167 (18 cm x 24 cm)</td>
</tr>
<tr>
<td>Science — Grade 7</td>
<td>166 (18 cm x 24 cm)</td>
</tr>
<tr>
<td>Science — Grade 8</td>
<td>226 (18 cm x 24 cm)</td>
</tr>
</tbody>
</table>

In addition to the teachers’ guides and pupils’ texts, the committee produced sample test items and prototype question papers for evaluating pupil performance in the new curriculum.

Resources

The Ministry of Education has adopted a strategy for the development of science education by providing facilities for teaching science to all pupils, especially those in rural areas from grades 6 to 9. Whereas up to 1972 science teachers and laboratory facilities were available for teaching science in only about 1,000 schools at the junior secondary level, the Ministry was faced with the problem of supplying science teachers and equipment for about 7,000 schools in a short space of time. The Ministry was forced to adopt a crash programme to meet this demand.

1. Recruitment of teachers

At the end of 1971, just before the new science programme was introduced, there were three major categories of science teachers in the schools:
i. University graduate teachers. These teachers, some of whom had postgraduate qualifications (e.g. Diploma in Education), were teaching almost exclusively in grades 11 and 12 (G.C.E. Advanced Level).

ii. Trained teachers. These teachers, who had completed a two-year professional teacher education course in a teachers' college (special science) after ten years of school education which included at least two science subjects (chemistry, physics, biology), were teaching almost exclusively in grades 9 and 10 (G.C.E. Ordinary Level).

iii. Science assistants. These were untrained teachers who had passed at least the G.C.E. (Ordinary Level) examination after ten years of schooling with at least two science subjects. Some of them had also completed a G.C.E. (Advanced Level) course in four science subjects (chemistry, physics, botany, zoology, pure mathematics, applied mathematics). They were teaching mainly general science in grades 6 to 8.

The increase in the number of science teachers in categories (i) and (ii) above is severely limited by the intake to the science faculties of the university, and the special teachers' colleges.

It was not possible to meet the demand for the 4,000 to 5,000 new science teachers from the above two categories. The only practical solution was to recruit more teachers of category (iii) to meet the immediate demand. There was a large pool of G.C.E. (Ordinary Level) and (Advanced Level) qualified young men and women from whom the selection could be made. The criteria for selection were:

a. Academic qualifications (merit given to G.C.E. Advanced Level passes, distinctions and credits in science subjects at G.C.E. Ordinary Level).

b. Willingness to serve in remote rural districts under difficult living conditions.

Starting from 1971, the numbers of such teachers appointed were as follows: 1971 — 3084; 1972 — 3144; 1973 — 1875; 1974 — 450.

These young men and women, after a preliminary briefing, were sent to schools having no science teachers. A continual in-service training programme was organized to help them.

2. Laboratory facilities and equipment

Prior to the introduction of the new science scheme in 1972, only about 600 schools had laboratory facilities and equipment for teaching science. These few schools had fairly well equipped science laboratories sufficient to teach chemistry, physics and biology up to G.C.E. Ordinary Level. Of these schools about 200 had facilities to teach chemistry, physics, botany and zoology up to G.C.E. Advanced Level. With the introduction of the integrated science
programme basic facilities needed to teach integrated science had to be provided to about 5,000 schools.

Almost all of the laboratory equipment, materials and chemicals were imported at considerable cost in foreign exchange. With limited foreign exchange allocations available for science equipment, the Ministry was faced with a problem of meeting the increasing demand for science equipment.

Fortunately, formal laboratories and traditional science equipment were not needed for teaching integrated science. Pupil activities and teacher demonstrations were designed especially with the limitation of material resources in mind. Standard minimum lists of equipment were prepared for each grade, and several types of sets of equipment were assembled and dispatched to schools. In 1971, 3383 science equipment kits were supplied to schools for teaching science in grade 6; in 1972 the same 3383 schools were supplied with equipment kits for teaching science in grade 7. This was followed in 1973 and 1974 for grades 8 and 9. The remaining schools, which were not supplied with equipment, were about 1500 in number. They were very small schools containing less than 5 per cent of the total enrolment in grade 6.

It was also recognized that a certain amount of equipment and material could be improvised out of things found in the environment. The teachers' guides gave useful hints on the production of improvised equipment. Workshops were conducted to provide teachers with the basic skills for making improvised equipment. Within a short period of time, teachers in all parts of the island, especially in rural areas came out with a large variety of improvised materials to replace the expensive imported equipment. Such improvisations included balances, kerosene burners, electric motors and materials such as litmus and pH papers (from local plant dyes). Materials such as polythene bags, tin cans, bottles, cigarette wrapping foil, milk can tops, empty ball-point pen refills, fused electric bulbs and used dry cells which were usually discarded into garbage cans became popular science teaching materials.

The Ministry also has its own science equipment production factory at Pattalagedera, where certain essential pieces of equipment are produced. At present the following are being produced at the factory:

<table>
<thead>
<tr>
<th>Item</th>
<th>No.</th>
<th>Value in Rupees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic beakers</td>
<td>8000</td>
<td>48,000</td>
</tr>
<tr>
<td>Plastic funnels</td>
<td>8000</td>
<td>40,000</td>
</tr>
<tr>
<td>Electric motors</td>
<td>1000</td>
<td>15,000</td>
</tr>
<tr>
<td>Wheatstone bridges</td>
<td>200</td>
<td>5,000</td>
</tr>
<tr>
<td>3-wheeled trolleys</td>
<td>2000</td>
<td>70,000</td>
</tr>
<tr>
<td>Pressure lamps</td>
<td>1000</td>
<td>12,000</td>
</tr>
<tr>
<td>Plastic pulleys</td>
<td>5000</td>
<td>60,000</td>
</tr>
<tr>
<td>Vernier calipers</td>
<td>1000</td>
<td>25,000</td>
</tr>
<tr>
<td>Laboratory stands</td>
<td>1000</td>
<td>15,000</td>
</tr>
</tbody>
</table>
A Science Equipment Design Unit has been set up at the Curriculum Development Centre.

Supporting services

In-service education

Most of the teachers teaching the new course were new recruits who had no professional training. Even in the case of experienced trained teachers there was a need for in-service training since the content and approach were different from the traditional science courses previously taught. It was obvious that an intensive in-service education programme was needed for the success of the new integrated science teaching project.

The in-service education programme was also designed and organized by the Curriculum Development Centre. A group of experienced science-trained teachers was selected. This group was brought to the Curriculum Development Centre and participated in seminars and workshops organized by the science curriculum committee to give them the necessary understanding and ability to conduct in-service education study circles for the new recruits. These teachers, who came to be known as in-service advisers or master teachers, were released from their normal teaching duties to do full-time in-service education. They were attached to the regional education offices. There are 43 such in-service advisers functioning now. They conduct regular sessions for the teachers in their regions. The usual mode of operation is to invite a group of about 30 teachers in a particular circuit to a school which is centrally located and to conduct a one-day study circle covering the content which will be taught during the following four to five weeks. At the end of this period, another study circle will be held to cover further ground for another four to five weeks or so. By this arrangement, a teacher is expected to be exposed to about 45 hours of in-service education a year. The in-service advisers are also given regular briefing by the curriculum committee through seminars, workshops and residential vacation courses organized by the Curriculum Development Centre.

Educational broadcasts

The Educational Service of the Sri Lanka Broadcasting Corporation has also been utilized to serve the new science project. A joint committee of educationists from the Curriculum Development Centre and broadcasting personnel from the Sri Lanka Broadcasting Corporation have drawn up a programme for educational broadcasts to meet the needs of teachers and pupils in the integrated science course.

Science Equipment Design Unit

There was a two-fold need for setting up a design unit. Firstly the scarcity of foreign exchange for importing science equipment created a need for exploring local
resources for producing inexpensive equipment using local raw materials as far as possible. Secondly, modern trends in science teaching demand the use of new equipment and materials suitable for pupil activities. The Science Equipment Design Unit set up at the Curriculum Development Centre consists of experienced science teachers with a special aptitude for designing and constructing science teaching equipment and a technician with wide experience in producing, servicing and repairing science equipment.

The main objectives of the Science Equipment Design Unit are as follows:

i. design simple, low-cost equipment and apparatuses for teaching science and mathematics;

ii. design apparatuses that may be constructed using locally available raw materials and other resources;

iii. design apparatuses that are functionally sufficient to provide the necessary learning experiences both during teacher demonstrations as well as during pupil activities.

The design process consists of the following steps:

i. Analysis of course and decision on priorities;

ii. Preparation of list of specifications;

iii. Designing prototypes;

iv. Test for performance;

v. Preparation of student work sheets;

vi. Field trials in schools — observation of pupils' handling, item performance, problems in use;

vii. Improving or modifying design;

viii. Preparation of drawings and lists of materials;

ix. Production of prototypes at the factory;

x. Field trials by in-service advisers in regional schools;

xi. Preparation of final blueprints for mass production.

The Unit obtained the services of a Unesco consultant and a British Council — UNICEF consultant for short periods. The Design Unit which is situated at the Curriculum Development Centre is working in close collaboration with the Science Equipment Production Factory at Pattalagedera.
IV. PLANS FOR REVISION

Preliminary work on the next cycle of revision of the integrated science curriculum has already begun. The revision will be done by a group of teachers who have had first-hand experience in teaching the course for three to four years, especially in the rural schools. Feedback about the actual field situation is being obtained through seminars and questionnaires, from teachers, in-service advisers and field supervisors. School visits by Curriculum Development Centre personnel also provide direct feedback. Pilot tests have been conducted to determine the level of achievement and areas of difficulty. Diagnostic tests are also being planned in certain units to determine student difficulties.
The titles appearing in the Asian series were prepared by educators in Asian Member States at the request of the Asian Centre of Educational Innovation for Development which is associated as one of the partners in IERS.

The Asian Centre of Educational Innovation for Development at Bangkok (Thailand) is a co-ordinating mechanism for a network of national centres and institutions in the Member States in Asia through which educational innovations relevant to the development needs of participating Member States are promoted.