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# CURRICULUM DEVELOPMENT

in

# INTEGRATED SCIENCE

for

# FORM ONE to FORM THREE

in

# MAURITIUS

A thesis presented in partial fulfilment of the requirements for the degree of

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* * * * *

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# GLOSSARY

A.S.E - Association for Science Education

C.J.S.E - Certificate of Junior Secondary Education

I.C.S.U - International Council of Scientific Unions

M.I.E - Mauritius Institute of Education

M.I.S.P - Mauritius Integrated Science Project

S.C.I.S.P - Schools' Council Integrated Science Project

S.T.E.P - Science Teacher Education Project

U.N.D.P - United Nations Development Programme

# C O N T E N T S

# ABSTRACT

During the past decade, Integrated Science curricula and courses have mushroomed all over the world. Likewise the Mauritius Integrated Science Project came into existence in 1976. Implied is that this 'new' science course is also a 'better' course. Is it and can it be improved?

After retracing the history of Mauritian education and showing how the education system was shackled to the powers that be, mention is made of how the wind of change started blowing over the education system. The birth of M.I.S.P is hailed; its aims and objectives are then discussed. This centres on the meaning of Integrated Science, its composition and where M.I.S.P stands with regard to it.

Philosophical concerns for the nature of science, the relevance of science education as well as the social implications of science education,all these concepts are treated at length. It is the thesis of this author that if these three concerns are not taken into consideration in curriculum development work for a science course at primary and secondary education levels, then we would only be scratching the surface. In consequence, an in-depth analysis of the scientific method is called for. How far the M.I.S.P teaching approach diverges from this scientific method is then exposed.

The dichotomy between the process of science and the product of science is fully discussed. It is suggested that school science, based essentially on the product of science, despite teaching approaches to the contrary i.e guided discovery method, will do more harm than good. It is proposed that the process is the all important factor in science education. Learning through science rather than learning science is upheld to be the goal of science education. Scientific thinking should predominate over scientific knowledge at the level of education under consideration. This is said to have survival value and is viewed as the Education for Tomorrow.

Proposal for changes in the structure and contents of M.I.S.P is made. The implementation issue is emphasised, especially in terms of teacher training and examinations. These two factors are considered essential to the success of M.I.S.P. Otherwise a new orthodoxy will set in.

# INTRODUCTION

In the Indian Océan, just within the Tropic of Capricorn and about 1500 miles from the east coast of Africa, lies Mauritius. Although it is approximately 40 miles long and 30 miles wide, its area is 720 square miles. Yet its population is estimated at 910,000 in 1978 (Bi Annual Digest of Statistics, December 1978, Vol. 13, No.2, Central Statistical Office, Rose Hill, Mauritius). It is divided into (a) Indo-Mauritians, 65% (b) the general population comprising people of European descent and of mixed or African origin, 32% and (c) Sino-Mauritians 3%. Such a heterogeneity of the population is reflected in the linguistic and ethnic differences and by the plurality of religious demoninations. As a result of such varied cultural and linguistic backgrounds, a rather cosmopolitan attitude has been inculcated in the population; however a desire to preserve the cultural links with the countries of their forebears still persists.

The History of the island was one of transient settlement by the Portuguese, then came the Dutch who named it Mauritius in honour of their ruler, Prince Maurice of Nassau. The French colonized it in 1721 and re-named it the Ile de France. Finally the British conquered it in 1810. By the Treaty of Paris, signed in 1814, the Ile de France was ceded to the British and re-named Mauritius. Under the terms of surrender the cultural life of the inhabitants was safeguarded and the religion, laws, language, customs and traditions have been preserved to this day. The British

Crown Colony of Mauritius finally became an independent state in 1968. Though the official language is English, the lingua franca is the creole language, a sort of pidgin French which is spoken rather than written. Most of the local newspapers are written in French. Of course, the various ethnic groups more or less still treasure their mother tongues embracing a multitude of Asian dialects. Thus Mauritius is a centre of both Eastern and Western cultures in the midst of the Indian Ocean.

A brief study of the socio-economic and political bases of the colonial system of education as it has existed over the preceding historical periods and as it persists in Mauritius, may light the road ahead for reconstruction.

# CHAPTER 1

## EVOLUTION OF SECONDARY EDUCATION

### 1.1 Historical Background of Mauritian Education

A study of the educational developments in the colonial society of the Island of Mauritius has shown, through a background of social stratification, the economy and the polity, that both the French and British colonial systems of education were not based on an assimilationist ideology (Prithipaul 1976) ...

During both regimes, the educational system was closely geared to the policies of social control and economic exploitation used by the respective colonising powers. Its content was determined either by the colonial government that was in power at different times or by such dominant groups in the society as were able to acquire a participatory role in the management of education. There is a measure of convergence between the findings of Prithipaul (1976) and the insights reached by the British sociologist of education, Michaël Young (1971: 24-41), he described how dominant social or professional groups do utilise the school system to legitimise their position of superiority by means of the organisation and selection of knowledge, and in establishing the appropriate evaluative channels, to set their class apart from the rest of society.

In the case of Mauritius under British rule, there were other dominant groups such as the French upper classes who asserted their cultural superiority through the medium of the educational system. Hence the development of educational systems stemmed not from the point of view of manpower needs generated by the diversification or expansion of the economy only, but also in terms of its effectiveness in ensuring a certain type of economic and political control which was typical of the colonial society at different times. During the British colonial era, the educational system became bilingual and bicultural. When soon after the 1880's all examining privileges were delegated to English University Examining Boards, the measure helped perpetuate the belief in the permanent and unchangeable character of the curriculum in the very few schools in Mauritius. Besides the bilingualism, the Mauritian school came to inherit the same organisation pattern and curriculum as a British grammar school (Prithipaul 1976).

However, British rule resulted in rapid economic development and many fundamental social changes. A significant event in 1833 was the abolition of slavery when a large number of freed slaves, of African origin, refused to continue working on the land for sugar cane production. To replace them, the French planters recruited indentured labour from India. With this labour force and improved methods of cultivation, sugar production expanded considerably during the succeeding years until it has made the sugar industry, the backbone of the island's economy.

Efforts, however, have been made to lessen dependence on a single crop economy by encouraging other forms of agricultural and industrial development, tea and tobacco being already among the most important secondary products. Light industries have been started to manufacture clothing, shoes, soap, edible oil and so on, with a view to diversifying the economy. The island has no mineral resources of its own.

The secondary educational institutions of Mauritius have functioned along the model of the English Grammar School. It was only just before Independence that Mauritius had a University established in order to upgrade technical and managerial skills (Mauritius Annual Report 1967:69). Previous to that, there was no institution for higher education. Students had to go abroad for University training, mostly at their own expense since scholarships were scarce. Moreover, as education was considered the pathway of social mobility, higher education became a must for those who could afford it and was directed towards fields of employment that were most remunerative.

The problem of education does not stem essentially from lack of educational services. Instead, it would seem to lie in the area of developing an educational system that takes into consideration the economic, socio-cultural and political features of the island. Most, if not all schools are bi-lingual, in spite of the multi-racial and multi-cultural society. Such a society with different ethnic groups sharing the same polity and bound by the same economic structure, needs an educational policy which can contribute to greater socio-economic and cultural integration among the different ethnic groups. This implies that, besides equality of educational opportunity at all levels, a curriculum must be devised which reflects the religious, cultural and linguistic heritage of each community rather than short-term economic success in order to bring about the cultural and emotional integration of the different ethnic groups. Hence there must be a basic understanding of the structure of the Mauritian society as well as the political goals of the people so as to attain some degree of congruence between education and the 3 major institutions basic to a human society:

| | |
|---|---|
| EDUCATIONAL SYSTEM | POLITY |
| STRATIFICATORY SYSTEM | ECONOMY |

1.2 Rationale for change in Secondary Education

The necessity for change was given official sanction in the terms of reference of a recent Commission of Enquiry on Secondary Education (Glover Report 1978) which included, amongst other recommendations, the following:

(a) To consider problems arising out of the changing needs of the country, bearing in mind the relationship of Mauritius with the international community;

(b) To make recommendations, having regard to the social, cultural and economic circumstances of the country.

Previous to this, the Mauritius Government 1972-1975 Plan for Social and Economic Development had set in motion the machinery required to transform the old education system of Mauritius into a modern one geared to meet the requirements of a newly independent nation. It stressed the need to broaden the educational structure in order to provide students of various aptitudes with an education relevant to the needs of a fast changing society. During this plan period, educational development will be adjusted to meet the socio-economic needs of the country. In particular, steps will be taken to diversify the curricula and to make an integrated approach to the concept of education as a life-long process for the development of a well-balanced.personality.

Two previous Committees of Enquiry, the Richard Committee of 1965 and the Ramphul Committee of 1973, had pointed out in varying degrees, the unsatisfactory state of secondary education in Mauritius. However, none of them made proposals which were sufficiently firm and far-sighted to cure the ills which they had themselves pin-pointed. It was only in July 1976 that Unesco, in a report prepared following a visit to Mauritius by one of its missions, recommended the best, indeed the only appropriate, solution to the problem, which is direct and massive Government participation in the running and control of secondary education.

Consequent upon this came the historic decision made as soon as the present Government came to power after the last general election in December 1976 to introduce free secondary education in Mauritius. Moreover, this momentous step, for which quite clearly there had been no sufficient planning, appeared to catch everybody off balance and a rather chaotic situation developed when schools resumed in January 1977 - which prompted the Government to set up the Glover Commission of Enquiry for Secondary Education.

The Commission found that there was general consensus on:

(a) The need to provide at least three years of general post-primary and secondary education up to the age of about fifteen which is the minimum age for employment.

(b) Teacher training, or rather the need for an expanded system of teacher training, in particular, the lot of the teachers in private secondary schools was said to require special attention.

(c) The need for a national examination at the end of the third year of secondary schooling which would determine whether the pupil was fit for two further years of academic training or whether he was more suited to a technical form of education or still further, whether he should not straight away be diverted towards the labour market with appropriate training, if necessary.

(d) The dangers of producing a mass of uniform citizens who did not know how to think and to solve problems.

(e) The separation of occupational training from the provision of a general broad-based secondary education.

(f) The setting up of teacher centres or teacher resource centres.

## 1.3 The Whys and Means for change in Secondary Education

As a result of the recommendations of both the Richard and Ramphul Committees of Enquiry for the educational development of Mauritius, the Mauritius Institute of Education Project was approved in 1973 with the following inter-related commitments:

(a) Curriculum Development and Research
(b) Teacher Training
(c) Examinations

The Project Document (UNDP - Mauritius 1973) gives the following details:

1.31. Background

There has been a deepening concern with evident maladjustments at all levels of schooling, particularly in the area of curriculum teaching, for example, between the formal inherited pattern of a selective educational programme sorting out those who continue education and the social and economic realities of a society moving from sole reliance upon a single, highly industrialized agricultural crop to a predominantly industrial economy; between a rapid expansion of education in the private secondary schools and a lack of professionally trained secondary school teachers; between a curriculum suitable for urban education in England of some years ago and that needed by the citizens of an island nation in a different historical, geographical and cultural milieu.

The 4 Year Plan for Social and Economic Development (see 1.2, P.5) calls for an accompanying change in the quality and content of education from a generally academic emphasis to a more technical and vocational orientation at all levels. The Plan also stresses the vital role teacher training assumes in securing these changes. More specifically, the objectives in the plan for basic education at the primary and secondary levels are:

(a) Free education for all children at the first level (primary);

(b) Opportunity for secondary and vocational training for at least 60 percent of the boys in the age group 15 - 19 by 1980;

(c) a balanced curriculum which will include technical subjects and integrated science at all levels;

(d) technical and vocational orientation of education at the secondary and post-secondary levels;

(e) equality of educational opportunity for all according to their educational potential.

The Government of Mauritius is wholeheartedly committed to the realization of the above objectives and work towards their achievement has been underway for some years.

1.32 Justification for the Project

In the Mauritius 4 Year Plan for Social and Economic Development it has been stated that the most important resource of Mauritius is its manpower and that a well motivated labour force possessing the requisite mental and physical skills for a modern economy is the most valuable national asset. In order to meet the demand generated by prospective economic development, emphasis is being placed not only on increasing the availability and range of secondary education but more importantly, on improving the quality in terms of efficiency and the suitability to national needs and aspirations. The Government has therefore initiated the setting-up of an Institute of Education.(Mauritius Institute of Education Act 1973).

(a) Curriculum Development and Research

With the achievement of participation of very nearly the whole of the nation's children in primary education and with an increasing number patticipating in secondary education, there is emerging a growing concern as to the adequacy of the existing pattern of teaching and learning in the schools. At the secondary level this concern relates, in the context of Mauritius, more particularly to the several language skills so important,in a multilingual society, to the adequacy of numeration skills and related mathematical concepts, to the knowledge, skills and attitudes that are relevant to an active understanding of the physical and biological environment and to problems of enriching the curriculum with the purpose of selecting activities that have relevance to the world of work, and to a society where technology is playing an increasing part.

A major concern of the Government lies in the area of Curriculum Development, there being an urgent necessity to systemize this area of work. The breadth and complexity of the curriculum development process are often underestimated. The planning of new programmes and the writing of modern textbooks and teacher's guides that reflect the latest developments and are responsive to national needs involve much time, call for expert guidance, and clear identifications of the elements involved.

In such a context a Curriculum Unit should be set up within the Institute. This Unit should develop the work of the Curriculum Development Committee which has been already established. The major effort of this centrally co-ordinated, institutionalized centre will be on the development of programmes and materials that represent the best in modern thinking and that are oriented to the needs of Mauritius.

(b) Teacher Training Function of the Institute

The Government decision to develop curricula entails a new approach to teacher training. Further, latest figures available (October 1971) indicate that there are 1,763 teachers in the private and public secondary sector. Of them only 82 are trained graduates, whereas 313 are untrained graduates, 569 possess higher school certificate and are untrained and 84 have no qualifications. The staff/student ratio is approximately 1:30. Since under 5% of the total teachers' force is trained, the urgent requirement for teacher training at secondary level is clear. The position will be further aggravated by the proposed extension of the public sector by four new secondary schools including a sixth form college and by increasing demand made upon the private sector by an approximate annual output of 18,000, that is 90% of 12 year old pupils who do not obtain state aided education. Further, the majority of teachers in subjects that have a practical emphasis, e.g. technical education, commercial subjects, art, crafts, music, physical education and home economic and agriculture have no formal training whatsoever. This is particularly so in the primary and secondary schools. Yet it is precisely in these areas where Mauritius has a mushrooming need. Other than for a limited amount of of postgraduate work, substantial teacher training courses, both in-service and full-time, will normally include an upgrading component in the chosen teaching subject.

(c) Examinations

In the past, classroom activities in Mauritius have tended to be dominated by academic work and preparation for examinations almost to be exclusion of all other activities. The characteristics of examinations permeate the pattern of work and the emphasis within the classroom. In so far as the passage of the pupil through the school system and the possibility of participation in the world of work are governed in significant terms by examinations and the certification linked to it, the examinations will play a relatively dominating role in the school system until such a time when it recast. However, since the curriculum is to be enriched, learning to be made more interesting and relevant at both the primary and secondary levels, the examination system should lose some of its influence on work in schools. In this context the education of teachers should enable them to use enough innovation in the teaching-learning process to minimize memorization and encourage discovery and problem solving approaches.

Examinations in general have been conducted jointly with external bodies and this has entailed a certain degree of lack of flexibility. An Examination Board will be set up within the Institute with a view to increasing the adaptability and efficiency of the present examination system.

These commitments are specified in terms of Educational Objectives both long-range and immediate, as follows:

1.33 Long-range Objectives

The Government has initiated the setting up of the Institute of Education and has requested this project to assist in achieving the following long-range objectives:

(a) To act as a catalyst in the education system and guide it to meet the needs of the country. Research will be a major function of the Institute and the Centre will undertake studies in identifying national requirements and translate them into curricula specifications, with special attention to bridging the gap between general education on the one hand and technical and vocational education on the other.

Issues and problems of particular consequence are:

(i) Identification of the general and specific objectives of education in relation to the national, social, economical and cultural aims of the country.

(ii) The harmonisation of study area objectives with overall national objectives.

(iii) The translation of such objectives into functionally active instructional sequences implementable in the classrooms.

(iv) The re-examination of the criteria by which study areas are selected for inclusion in or exclusion from the curriculum and the re-examination of the criteria by which resources are allocated to the study areas.

(v) The guiding of trial implementation of revised curriculum.

(vi) A re-examination of Curriculum Development methodology embracing the best current views in educational thinking, for example, the consideration of inter-disciplinary and problem solving approaches in education;

(b) to improve the quality of primary and secondary teachers by providing appropriate in-service training courses and, with the assistance of the University Authorities, develop suitable methods of certification for teachers, particularly at the secondary level;

(c) to develop, test and evaluate learning materials including new teaching texts, audio-visual materials and teachers' manuals, which will incorporate new curriculum content and methods, using where possible indigenous resources and involving teachers and students alike in these activities;

(d) to incorporate activities presently performed by the Mauritius Examinations Section pertaining to the development and administration of examinations and to study reform and certification at the Primary, Secondary and Post-Secondary levels.

1.34 Immediate Objectives

In order to facilitate the achievement of the long-term objectives, certain immediate objectives may be identified:

(a) A department of Medium and Curriculum Research and Development shall be set up within the Institute. This project will assist the Curriculum Department in the formulation and implementation of a phased curriculum reform and development programme and to this end will:

(i) initiate a research programme and supervise studies of direct relevance to reaching curricula decisions;

(ii) co-ordinate, plan and write curricula materials by translating defined study area objectives into sequential instructional programmes, as indicated in the Four Year Plan. Emphasis will be accorded to practical subject areas in Woodwork, Metalwork, Technical Drawing, Agricultural Education and fields of language study;

(iii) supervise the preparation and development of modern syllabuses at the primary and secondary levels including learning materials, teaching texts, teachers' manuals, visual aids, etc;

(iv) supervise the gradual trial application of new materials and methods at the class level and evaluate their use. Necessary adaptations on the basis of these findings will be recommended;

(v) Analyse the strength and weaknesses of the present examination system and make necessary recommendations for the integration of the examinations with the new subject approaches within the schools;

(iv) advise on literature searching and on the dissemination of information together with the development of a Resources Centre.

(b) In the area of teacher training the project will assist the Institute to:

(i) continue and intensify the development of in-service training programmes with a view of bringing secondary teacher training into one continuing programme up to the level of the Bachelor of Education (B.Ed) degree for selected candidates.

(ii) initiate and supervise training programmes for the supply of teachers with the requisite subject expertise and professional training including the various aspects of educational technology;

(iii) integrate theory and practice as well as pre and in-service into the training programmes and use regularly suitable educational technology such as micro-teaching;

(iv) develop administrative and supervisory training for inspectors, headmasters and senior teachers;

(v) supervise the establishment of master, co-operating teachers in schools which will be used for practice teaching;

(c) The nucleus of a Mauritius Examination Syndicate will be established within the Institute. The project will assist this unit to:

(i) assume responsibility for the entrance and certification examinations of Teachers' Training College (for primary schools);

(ii) assume gradual responsibility at the standard VI primary school leaving certificate level;

(iii) assist the Government in implementing decisions to be taken with regard to the Form III (age 14/15) examination, a selective examination for pupils leaving school after two unsuccessful attempts and those going on to higher academic studies;

(iv) design, pre-test and apply suitable measuring instruments to evaluate the knowledge and attitudes obtained through the use of curriculum materials produced at the Institute;

(v) develop and conduct courses in Research Methodology, Testing and Measurement for local staff and train counterparts in teaching these subject areas.

(d) The project will keep in view the need to articulate the work of the Institute and Teachers' Training College such that they work together on common institutional and teacher educational problems.

1.35 Investment Potential

Though it is difficult to work out the economic rate of return of the project, the indirect economic benefit that will accrue to the economy as a result of the implementation of the project, designed to lead to the formation of the human capital required for accelerating the economic development, should not be underestimated.

# CHAPTER 2

# The Mauritius Integrated Science Project

## 2.1 History of the Project

The Mauritius Institute of Education (M.I.E) started its operations in January 1976 with two of its main functions, namely Teacher-Training and Curriculum Development. The training course is a two-year full-time or three-year part-time course involving studies in education, two subject fields (for example, English and French or Biology and Chemistry) and teaching practice, leading to a Diploma in Education certificate (an undergraduate course). Integrated Science was not offered as a subject field of study for teacher training until two years later because the learning materials for schools were then being planned, organized and in the process of being written as trial material to be used in pilot schools. The Integrated Science syllabus for teacher-trainees stresses the need for keeping science as a core subject in the school curriculum and the advantages of an integrated course for pupils of Forms I and II, together with practical work from and discussions of methods and contents in M.I.S.P. Pupils' Books for years 1 and 2.

In fact, writing learning materials for pilot schools became the main thrust of the Curriculum Development work in the initial stages of life of the M.I.E.

The Integrated Science course for schools forms part of the 5 'Compulsory Broad Core' subject areas in the common curriculum leading to the National Form III Examinations (C.J.S.E), the other subject areas being English, French, Social studies and Mathematics. This C.J.S.E examination will be held for the first time in October 1981 and it is a selective examination (see 1.34(e) (iii) ).

The Mauritius Integrated Science Project (M.I.S.P) was originally meant to cover the first three years of secondary education, i.e. Form I to Form 3, for the pupil age-group II to 14 (see 1.31 (c) ). However, after discussions at meetings between teachers and the curriculum writers (Appendix A), it was decided to divide the project into 2 parts:

(a) an Integrated Science course for Forms I - II.

(b) a Form III Science course made up of loosely linked Chemistry, Physics and Biology courses.

In the end, M.I.S.P appeared in the form of trial learning materials as follows:

1976: Form I Integrated Science Pupil's Book and Teacher's Guide

1977: Form II Integrated Science Pupil's Book and Teacher's Guide

1978: Form III Science in 3 volumes as Matter & Life (Biology), Matter & Energy (Physics) and Matter & Its Reactions (Chemistry). Teacher's Guides will follow.

The Form III Science course was a compromise to allay the fears of specialist science teachers who wanted a foundation course leading to School Certificate (Form V) Examinations in Chemistry/Physics/Biology/Physical Science/ Human and Social Biology. It would be useful to quote what is written in the "Introduction" of both M.I.S.P Form I and Form II texts in order to outline the aims and objectives of the course and to compare them with the Educational Objectives (see 1.33 and 1.34).

The "Introduction" says:

M.I.S.P is a two-year course intended for the first two years of secondary schooling. It is written so as to suit children of all abilities and is published in four parts:

Year I Pupil's Books

Year I Teacher's Guide

Year II Pupil's Book

Year II Teacher's Guide

No previous scientific knowledge is assumed for those beginning the course, although it follows on the broad aims of the environmental science syllabus now being developed for primary schools.

This Form I and II course offers the same degree of integration as its elder brothers, the Scottish, Nigerian, East African and West Indian Integrated Science Projects; it is intended mainly as a contribution to general education but will also serve as a basis for the study of Form III Science (loosely linked Chemistry, Physics and Biology courses) leading to School Certificate in Chemistry/Physics/Biology/ Physical Science/Human and Social Biology.

PRESENTATION

Each year's book is a guide to activities to be performed by pupils. The sequence is graded, beginning with techniques

in science, e.g.,
measurement of time, weight, temperature ... followed by observation and experimentation on simple topics, e.g., air, water, substances, living things .... and leading ultimately to the formation of concepts, e.g., force, energy, resources, conservation.

While equipment required for this course has been kept as simple and as inexpensive as possible, every effort should be made by school and teacher to obtain sufficient equipment and materials so that the pupils themselves may carry out the activities. When material such as caterpillars, flowers, tin cans are required pupils should be encouraged to bring their own.

A teacher's guide is provided for each year's work. Finally, it is considered that the objectives of integrated science studies would be usefully stated here. These are given under three main headings.

KNOWLEDGE AND UNDERSTANDING

1. Recall of essential facts and concepts.

2. Ability to apply knowledge and understanding gained in formal experiments to new practical situations in everyday life.

3. A scientific understanding of important aspects of the local environment.

SKILLS

1. Emphasis on accurate observation, recording and interpretation of results.

2. Acquisition of an ordered approach to carrying out practical work. Tidiness and care are emphasised.

3. Ability to obtain an overview of the environment and relate different aspects of it to one another.

4. Ability to communicate with others outside the school about ideas and knowledge of science.

ATTITUDES

1. A taste for the active use of the scientific method as a useful tool in improving everyday life.

2. A taste for action both individual and collective; the value of teamwork.

3. A realisation of the importance of, and respect for, other living things in the environment.

4. Science has an important part to play both in the economic development and the preservation of the Mauritian environment.

Furthermore, M.I.S.P Form II text elaborates on the concepts of the environment and the scientific method of study. Thus on page (iv) of the text it is said:

> Themes 6 - 11 deal with the Human Environment - your environment. The main aim of these themes is to help you know and understand better your place within the surroundings in which you live, in the hope that you will come to appreciate it more and give more consideration to it. For it has been shown that there is a very close relationship between the quality of human life and the state of his environment.

It is necessary, throughout, to keep to the scientific method of study, i.e. come to no conslusion unless this has been verified by observation and/or experiment.

It is proposed that you utilise the following simple terms to describe the various steps in the scientific method.

| | |
|---|---|
| I observe ... ... ... ... | Initial observation |
| I believe that ... ... ... | Hypothesis |
| It is believed that ... ... | Existing scientific knowledge |
| I find out ... ... ... ... | Experimental verification |
| Now I know a little more ... | Conclusion |

Any conclusion is, of course, to be regarded as a a basis for further observation and hypothesis and not to be final.

Finally, the "Introduction" of each of the three Form III text-books (Matter and Life, Matter and Energy, Matter and its Reactions) to be studied concurrently adds:

> The main aim of this science 'package' in Forms I - III is the development of a scientific component to the general education the pupil is acquiring. It is hardly necessary to state the vital importance of science to education for the world of today and tomorrow

With the advent of free education in 1977 and the future introduction of the C.J.S.E examinations in the early eighties, all secondary schools had to start teaching the Integrated Science course as one of the five core subjects with effect ffom January 1978. Private schools came under the jurisdiction of a newly-created institution called the Private Secondary Schools Authority (P.S.S.A) whereas the State schools remain under the aegis of the Ministry of Education. So M.I?S.P was adopted almost overnight, its dissemination occurring without sufficient trialling. However, trialling did take place on M.I.S.P Year 1 at the end of 1976. A discussion of the results of the trials will be undertaken later.

## 2.2 Rationale for M.I.S.P

In the Project Document, mention is made, under the title of Basic Science and Environmental Studies, of the introduction of environmental studies in the primary school whereas for the secondary education sector, a study of science education will be undertaken by the Institute of Education to specify operational guidelines for developing an integrated science curriculum. No details are given as to what is meant by integrated science. It is left to the curriculum developers to decide what materials to produce taking into consideration "the need for Basic Science and the general education to be provided for the needs of the country".

The curriculum developers fell back on work already pproduced in the Integrated Science field, namely the Scottish Integrated Science, the West Indian Integrated Science, the Nigerian Integrated Science and the East African Integrated Science, to the extent of having the <u>same degree</u> of integration. This is stated in the Introduction of both M.I.S.P. Book 1 and Book 2. However, no mention is made of the sort of integration that has been used. It is not as if the curriculum developers wanted to make a 'pot-pourri' of the various integrated science schemes; rather these schemes served as beacons along the unfamiliar routes which the curriculum developers have had to map out.

Thus, as in the Scottish Integrated Science Curriculum, the syllabus is designed to be essentially process-based and taught almost totally by laboratory work itself performed by pupils, including field work. It is an integrated science syllabus made up of topics from Biology, Chemistry and Physics together with a heavy emphasis on environmental studies. How much integration is there of the topics of the various subjects is a matter to be debated in the light of what is meant by integrated science or of what integrated science studies stand for in a given context. However, the environmental studies in M.I.S.P form a starting point for the integration of the sciences, especially biology, chemistry and physics. On the <u>Integration</u> Matrix proposed by Blum (1973), the Scope of M.I.S.P covers 3 science disciplines whereas its intensity is a loose combination of these disciplines, and in certain themes, the topics are unashamedly studies in biology, chemistry and physics. They are not, though, classified as such. In Science Form III, the learning materials are unreservedly topics in biology (Matter & Life), chemistry (Matter & Its Reactions) and physics (Matter & Energy)

The objectives of M.I.S.P have been set out in detail in Chapter 2 (2.1) based essentially on knowledge and understanding, Skills and Attitudes. Finally a brief review of an evaluation of M.I.S.P Form I undertaken in 1976 will now be given. This evaluation is based on the end-of-year Evaluation Test administered to all the 24 pilot shcools in October, 1976, i.e at the end of the first year of trialling of M.I.S.P Form I.

## 2.3 Evaluation of M.I.S.P Form I

The Test Paper was made up of two sections: A and B; and pupils were required to attempt all questions set in them. Section A was of the multiple-choice type with one right answer out of 4 alternative answers. Section B was of the structured type with 4 questions made of several parts.

An analysis of the Test Paper showed that the majority of items were meant to assess knowledge and understanding; fewer items were meant to test skills - of the "process" type (in contrast to the "manual" skills) - and none was set on <u>attitudes</u> as such (Chung 1977).Chung (1977:24) found that, whilst assuring a fair level of pass (86.0%) in the best schools, this Integrated Science paper would result in a 37.8% pass in the weaker schools, the pass mark being 50%.

Chung (1977:28) added the following:

(a) There is some strong feeling that the level of the course is too high for the pupils in Private schools (weaker schools). Such topics as "chromatography" is being skipped as it is thought to be too difficult. The State Schools, however, find the Units rather easy and some have expressed concern over the level of constituent subject fields which will be taught in subsequent years.

(b) It is abundantly clear thatmany schools - the "Private" ones in particular - lack necessary equipment and facilities. This surely affects the quality of teaching which is expected in this new approach (process) and is probably affecting pupil performance in the pilot schools.

(c) The <u>teaching Units</u> themselves are to be written in a clear, simple language the choice and level of which is to be "standardised"; technical terms which are thought to be indispensable must of course not be left out.

(d) Giving advice to teachers/groups of teachers via school visits could prove to be extremely helpful in the sense that there is "individualised" attention and direct applicability to particular topics being dealt with at the time. This technique, however, has limited scope - both in terms of time spent and syllabus coverage - when it is compared with the seminars orientation course where teachers are genuinely given the opportunity to delve into all sorts of unthinkable problems connected with their trade.

(e) The biggest constraint is doubtless the big gap between the academic performance in State schools and that in the large majority of Private Schools. The attainment of a pupil in Integrated Science in a state school is thought to be on the average one-and-a-half times better than that of his/her peer in a private school.

(f) The present Report must not be taken to imply, as Stenhouse (1975) would have put it, that the Curriculum Project is always "to go for solutions rather than for problems" - otherwise, many problems concerning the educational advancement of this country would continue to be neglected, as of old.

(g) Indeed, the best guarantee for a curriculum project to continue its existence and to thrive is to have evaluation research placed in the forefront of its activities. Curriculum development and its evaluation are integral activities: one of the most potent seed-beds for a "modernised" curriculum in the local scene lies in the interplay between the Examining Body (see Project Document*) and the schools and the teachers in them. The examination will provide the ultimate lever that will help push the curriculum through when everything else seems to have failed!

In a nutshell, this initial evaluation illustrates the weaknesses inherent in a teaching approach, a process one at that (in fact, it is the guided - discovery approach which is used), whereby the end-result is the acquisition of knowledge through understanding. However, it must be stated that, in addition to the Integrated Science course being newly introduced in schools, the evaluation work itself was going through its birth-pangs.

# CHAPTER 3

## THE CASE FOR INTEGRATED SCIENCE

### 3.1 INTEGRATED SCIENCE : A BETTER SCIENCE?

In a way, it can be said that integrated science education is the fashion of the day. For example, at the 1968 Varna (Bulgaria) Congress on the integration of science teaching, there were only 30 -40 integrated science courses in existence. This number has increased to, at least, 130 such curricula as reported at the 1978 Nijmegen (Netherlands) Conference on Integrated Science Education Worldwide (ICASE 1978). Implied is that this "integrated" science is also a "better" science. Is it? The answer lies in the curriculum development work laying the groundwork and setting the directions for this course in science education

Brown (1977) has documented the reasons for the proliferation of integrated science education on three major areas of concern;

(a) concerns for the nature of science

(b) educational concerns

(c) social concerns

The Varna conference drew attention to the significance of science eudcation as a component of general education, and the idea of "Education through science" has found widespread acceptance. At the lower secondary level a need has been felt for science courses which are of interest to the pupil and which make a real contribution to his general education. This may well lead to designing courses based on topics and issues closely related to his day-to-day experience. Such topics, by their very nature, often require an integrated or interdisciplinary approach.

Rutherford (1978: 43-44) has summarized the main reasons given for the teaching of integrated science based on assumptions about the natural world, science, students and societal needs. These are:

- The natural world is a unified whole. Our present lack of knowledge may prohibit us from perceiving that unity in all its complexities, but to the extent possible science should try to illuminate the whole rather than the mere fragment that each separate discipline concerns itself with. Questions: How can a teacher ever get to know enough about the astronomical, atmospheric, ocean, earth, biological and physical sciences - not to mention mathematics and the behavioural and social sciences - to be able to teach unified content? Unless teachers will agree to substantially broaden their knowledge of science by studying sciences outside of their own field, is there any way they can become prepared to teach an integrated view of the world (or any part of it)?

- Science itself, as distinct from nature, is moving toward integration in content and method. More and more separate conglomerates of knowledge are being assembled into a conceptually unified structure, just as techniques are shared across disciplines. The rapid development of molecular biology provides a dramatic but not a typical example of what happens when different sciences join hands. Questions: Can a teacher trained in substance, techniques and style of one science learn those things about one or more other science domains without extensive retraining? Can a teacher learn "integrated science" de novo? Will he even try if it takes him into areas of science about which he has no personal interest?

- Technical and career education aside, students are rarely interested in the kinds of question that relate

> to the theoretical structure of a given scientific discipline. Instead they wonder about the real world of their everyday lives. Such matters willy-nilly cut across discipline boundaries, and therefore so should science teaching if it wants to capitalize on natural student interest. Question: Since different students have different science-related interests, how can any one integrated science course deal with them any better than a discipline-structured one?

But the rationale for integrated science teaching based on claims that the universe is a unified whole and that science is becoming unified is criticized by Rutherford and Gardner (1968:49) thus:

> Grand philosophical notions about the "ultimate" nature of the universe are speculative at best, and certainly views counter to the "unity" one expressed above, are held by some philosophers. The modern trend, perhaps, is neither to affirm nor to deny the oneness of the universe, but rather to say that such speculation may be interesting but not terribly useful. Many scientists

would claim that what they are really doing is trying to solve limited problems that happen to interest them, whether or not the solutions of these problems contribute to the construction of any unified view of the universe.

- Similarly, it is the position of many contemporary philosophers and historians of science, not to mention scientists themselves, that conceptually and methodologically, science is not and cannot become totally unified. There are those who do not believe that eventually all of the natural phenomena of the world (whether chemical, biological, astronomical, geological, physiological, psychological, or whatever) can be organised and explained completely using physical laws. Those who take such a view can point out that even within the house of physics itself, unity is illusory, as evidenced, for example, by the need to rely upon such concepts as wave-particle duality and by the failure to develop a unified field theory.

- As far as the practice of science is concerned, it is no longer widely believed that there is such a thing as <u>the</u> scientific method. Instead there seems to be a variety of methods used by different scientists in different fields at different times. The biologist ordinarily cannot simply switch into chemistry, say, be a productive researcher. It is not only that he may not be up to date in his understanding of chemistry but also that he will be lacking in the investigatory skills appropriate to the state of the art in that field.

Moreover, the facets of the rationale that justify integrated science teaching in terms of student preferences and societal needs, are countered by Rutherford and Gardner (1968) by presuppositions such as:

- So-called real-life objects or events cannot be explained "holistically but only by bringing to bear knowledge from the individual sciences or subsciences.

- There is no agreement in sight on what particular knowledge is needed by scientifically literate citizens, on how sophisticated the knowledge needs to be connected with a particular societal concern.

- Certain kinds of integrated science issues do not address societal issues or student preferences any more than strictly disciplinary ones, and, conversely, certain discipline-oriented courses are able to deal effectively with both societal concerns and student interest.

## 3.2 WHAT IS INTEGRATED SCIENCE?

As the Varna Congress report put it, integrated science teaching requires "... joining several subjects into a single course in which the concepts of science are presented through a unified approach." Two conditions have to be met. One has to do with content, the other with format. In terms of content, examples include:

- courses that merely blend material from different sub-divisions of a single major discipline.

- Those that select material from two or more separate sciences (as in M.I.S.P).

- Some that join one or more of the natural sciences with mathematics or with material from the social sciences, arts or humanities.

- And those that put material from one or more sciences together with applied science and technology.

As for format, the diversity presented is even greater. Most of the courses that claim to be "integrated" can usually be placed in one or more of the following categories (Rutherford and Gardner, 1968):

- The Conceptual scheme approach in which the overarching ideas of science (conservation of energy, evolution, ecological balance, atomicity, plate techtonics, etc) provide the unifying thread.

- The inquiry approach in which solving problems and answering interesting questions about the natural world takes precedence over particular content.

- The relevance approach in which the content is organised around questions of the social utility and impact of science and technology.

- The process approach in which engaging students in doing science, any science, is considered to be more important than student mastery of a prescribed body of scientific knowledge.

Which type of integrated Science is best?
There is no straight answer to this question.

However, the point to remember is that the goal of general education in science is better expressed in terms of the quality and richness of the school science learning experience than in terms of the introduction of any particular kind of science curriculum, integrated or otherwise. At this point, it is necessary to give a meaning to the term "education" since M.I.S.P forms part of the Core subjects to provide a general education at the lower secondary school level (U.N.D.P - Mauritius Project Document 1973). As argued by Stenhouse (1972: 39), education, in its broadest and most general usage, is the process or product of a deliberate attempt to fashion experience by the direction and control of learning. Formal education refers to the process as it is carried on in schools. Does not this fashioning of experience, when appropriately done, lead to learning on one's own, i.e self-education?

## 3.3 WHERE DOES M.I.S.P STAND?

As stated before (see 2.2 p.31), M.I S.P is a science course for pupils with no previous knowledge of science.

Primary Science is still in the hatching stage. It is assumed that whatever acquaintance the pupils may have with science, they would have acquired it in an informal way. Now M.I.S.P., based partly on the Scottish Integrated Science course and some others, includes topics from the 3 basic sciences, i.e Biology, Chemistry and Physics. This science course is process-based and pupils learn science through laboratory work under the guidance of the teacher. In short, the course emphasizes guided-discovery in the learning of science or a heuristic approach. And the objectives of such a study aim at the acquisition of knowledge and understanding, skills and attitudes in science.

This thesis intends to show that, apart from being a pupil-centred strategy, the guided-discovery teaching approach is not much letter than the didactic approach in the teaching of science in so far as the cognitive domain is concerned. Of course, there are gains in the affective and psychomotor domains. Learning by doing, in many instances, enhances the interest and motivation of the pupil and builds up his confidence by training him in the use of his manipulative skills. What about his mental skills? This thesis will concurrently discuss how their development can be brought about through science education.

To a certain extent, the environmental studies in M.I.S.P go some way towards disproving tha above statement on the cognitive domain. All this argument will become clear in the ensuing discussion.

Finally, it is the contention of this thesis that it is neither the scope nor the intensity of integration of the science disciplines (see Blum 1973) which matters. The crux of the problem lies in a science education which takes into consideration the nature of Science and education and social relevance. Rather, the study of science should lead to the moulding of an integrated personality in the pupil. Not only does the pupil go to school to get numeracy and literacy, but scientific literacy must also form part of his general education.

What is scientific literacy? Showalter (1978: 37-39) has compounded the general objectives of science education into eight dimensions of scientific literacy because they represent eight directions along which every person should make a satisfactory degree of progress in order to be generally educated in science.

Thus, the scientifically literate person:

1. Understands the nature of scientific knowledge
2. Understands and accurately applies appropriate science concepts in interacting with his or her universe.
3. Uses processes of science appropriately in solving problems, making decisions, and furthering his or her own understanding of the universe.
4. Understands the values that underlie science and consciously choose to apply them or not in interacting with his or her universe
5. Understands and appreciates the joint enterprise of science and technology and the interaction of these with each other and with other aspects of society.
6. Has developed a richer, more satisfying, and more stimulating view of the universe as a result of his or her education in science and seeks to extend this education throughout his life.
7. Has developed numerous manipulative skills associated with science and technology
8. Has developed an ability to think on the formal operations level as described by Piaget and others

Showalter (1978) further says that the eight dimensions of scientific literacy offer a relatively simplified framework for science education objectives that has several psychological values such as:

1. Emphasis on a relatively small number of concepts each of which is very powerful thus enabling learners to discern the important from the trivial. These concepts provide powerful advance organisers that are applicable to a large number of subsidiary ideas and will in all likelihood be useful to the learner throughout life.

2. Emphasis on active doing rather than completely passive receiving especially in dimensions of skills and processes.

3. Emphasis on social relevance as in the dimensions dealing with science, society, technology and personal interest in science.

4. Emphasis on the affective or attitudinal domain as in the values dimension

5. Emphasis on cognitive development level so as to remove the most formidable barrier to further mature understanding of science.

As a group, the dimensions of scientific literacy not only reflect a unified science philosophy and a holistic psychology but also unite these two important determiners of how and what science shall be taught.

Note the terms how and what in relation to science education. These terms refer to the process and product of science, i.e the methodology and content of a science course. Whereas previously in the era prior to the curriculum development in science teaching (and learning) of the sixties, attention was focussed on the acquisition of scientific knowledge (the products of science or the ends), now the switch in emphasis is on the way to acquire scientific knowledge as well as retaining it (the processes and products of science or the means and the ends).

However, unless great care is taken, the ends can be mistaken for the means.

# CHAPTER 4

## PROBLEMS INHERENT IN M.I.S.P

A critical analysis of the learning material in the texts of M.I.S.P will now be undertaken to throw up the problems involved and tentative solutions will be looked for to carry through the curriculum development work in Mauritian education in general and in science education in particular (see Project Document p.12).

It is proposed to examine at first the various steps in the scientific method (see pp. 29 - 30), viz.

I observe ......... Initial observation

I believe that ......Hypothesis

It is believed that .... Existing scientific knowledge

I find out ............. Experimental verification

Now I know a little more .... Conclusion

in terms of the learning material produced and in relation to science education.

## 4.1 INITIAL OBSERVATION

The contents of M.I.S.P Book I are divided into 5 Themes. The first Theme has as title OBSERVATIONS AND EXPERIMENTS; Beginning with Page 1, the pupils are asked to start experimenting with THE BUNSEN BURNER, of which a diagram is given in the text.

To make the discussion clearer, a verbatim reprint of the instructions is set out as follows:

> Name the parts of the burner.
> Close the airhole. Turn the gas full on. Wait a few seconds then hold a lighted match about 2 cm above the burner to light the gas.
>
> What colour is the flame?
> Turn the ring to open the airhole fully.
>
> What colour is the flame now?
> This flame has two parts. The main flame and a blue pointed flame inside. Hold the gauze in the flame so that it is half-way up the pointed part of the flame.

Does the gauze get hot inside the pointed flame?

Hold the gauze just above the pointed flame.

What happens to the gauze now?

Turn the ring to close the airhole. Hold the gauze in the flame.

What happens to the gauze now?

Open the airhole again. Turn the gas tap slowly.

What happens to the flame?

What must you do

(a) to control the height of the flame?

(b) to make the flame hotter?

This guided-discovery approach in the teaching of M.I;S.P learning material is typical of all the activities to be performed by the pupils (divided into groups) during their science lessons. A cursory survey of the texts for Forms I to 3 will confirm this statement.

Such an approach is prescriptive in principle. The prescription seeks to develop certain skills such as the ability to handle scientific apparatus, to observe and record accurately and so on.

Many such activities involve strict obedience to a particular sequence of steps in the manner of a cookery book. If not, the 'answer' (in this case an observed colour-change in the bunsen flame) is not obtainable. Teachers and pupils are frustrated if a laboratory exercise does not 'work'. That is, the exercise does not consistently reveal the 'right' observation at the end of a sequence of instructions. Are not teacher-trainees or new inexperienced teachers advised to rehearse an experiment before facing their class? The idea is to save them from losing face in front of their pupils. They could, of course, use the 'wrong' result as an avenue for discussion and thereby teach some real science! But time is at a premium, and most teachers will not repeat laboratory exercises which have previously not 'worked'. Therefore a selection process has occurred. Most of the laboratory exercises which are in school texts will, with care,'work'. However, this selection process has brought with it major sacrifices.

Observation is played down. A quick glance at a colour change, or change in smell or a measurement may be all the observation which is necessary. This means that pupils are being shown by curricula what to observe. Consequently, what has to be observed must be made simple. This seems to be the desired aim of most practical exercises. However this strategy is not likely to produce significantly new observations or new interpretations in science.

According to Piaget and Inhelder (1969), observation is not simply the taking in of segments of external reality:

> "Biologists have shown that the relationship between an organism and its environment .... is one of constant interaction. The view that the organism submits passively to the influence of its environment has become untenable. How then can man as a 'knower' be a faithful recorder of outside events? When man acts upon and modifies the reality he obtains, by transforming his world, a deeper understanding than reproductions or copies of reality could ever provide".

This viewpoint is contrary to the Lamarckian position which holds that external pictures are apparently being taken into the brain as copies of external reality.

Tinbergen, an ethological biologist who won a Nobel Prize, attaches great importance to observation. He also emphasises this point:

"Naturally observation is always much more than the passive taking in of outside events; as many authors have pointed out, all observation is selective, and this selectiveness is determined from within ..... I believe that observers and experimenters can find common ground in acknowledging with prejudices, even with hypotheses and that we begin to wonder when we find, either at the observational or experimental level, that what we observe is contrary to our expectation; we are amazed at the refutation of what we expected and it is this amazement that spurs us on."

(Tinbergen 1972)

He further adds:

"Any philosophy of the behavioural sciences is going to have to face the problem of what actually happens when scientists do observe - what they bring to an observation, what they select from it - not assume it is a replication of the impersonal (allegedly) observation of the Physical sciences.

(Tinbergen 1972: 93)

It can be recognised that the process of observation is regarded as very important to science education. Furthermore, it is considered 'subjective' rather than 'objective'. This subjectivity viewpoint makes observation an extremely complex phenomenon. Firstly, all observers bring with them assumptions, often unconsciously held, - 'theories' to an observational situation. What they get from the observational situation varies from observer to observer. If the observational situation is in itself complex, then a number of observers may attain a wide variety of interpretations of the observational situation. It is probably this in-built observational variety which allows for interpretative variety. For example, Tinbergen and Lorens (both ethologists) do not always agree about similar phenomena (Tinbergen 1964: 521 - 539). Each does not passively submit to the phenomena being observed. Instead each reacts to the phenomena, and the products of this interaction vary a deal. This is a major implication for education which requires elucidation.

If observation of seemingly simple phenomena is variable among reputable scientists two possible strategies are open to education. The first is what seems to be hapenning at the present time. Pupils are being shown by curricula what to observe. Consequently, what has to be observed must be made simple. This seems to be the desired aim of most practical exercises. Moreover this strategy is not likely to promote significantly <u>new</u> observations or <u>new</u> interpretations. Theory is not advocated to assist in the interpretation of even the simplest observations. The pupils are not encouraged to interpret at all. They have little theory available to them in their courses with which to use as a basis. Therefore observation in current science education is a 'lowest common denominator' type where it is hoped that all pupils will apply exactly the same interpretations and meanings to identical phenomena. This may be sufficient for the training of technicians who need to acquire similar skills. However, it is not a strategy which will give science a forward looking orientation, where original interpretations are being given to observational phenomena. Current science education favours a position which relies upon knowing the past achievements. What is proposed is to allow for science to look to new possible interpretations. This will not necessarily be attained by attempting to make all interpret phenomena in the same way (an impossible situation anyway according to Piaget and Inhelder).

Tinbergen maintains that observation cannot be taught. It seems that current science education, in trying to teach observation, may be "banging its head against a brick wall". New interpretations will possibly arise only if observation is made more theoretical.

Tinbergen stresses that observation is a 'creative enterprise'. It is not pared down to a mere look or a smell which is the case in present science education. Questions are asked of the organism. This requires original and independent thinking on the basis of knowledge of theory. Observation is used to attempt to derive answers to these questions. Different theoretical orientations may develop different (and successful) ways of solving problems.

Another quotation highlights the need for upgrading observation:

> "It cannot be stressed too much in this age of respect for - one might almost say adoration for - the experiment, that critical, precise, and systematic observation is a valuable and indispensable scientific procedure, which we cannot afford to neglect. Particularly in our young science we need good observers and the sense of hurry, the urge towards spectacular "breakthroughs" must not be allowed to be a kind of contempt for non-experimental observation, which admittedly is a slow procedure but which, by trial and error processes, has to provide us with our hunches.
>
> (Tinbergen 1964)

For example, current biology attaches importance to observation but only in so far as it is related to practical work. Any other form of observation is "mere speculation" (Villee 1967; Weisz 1967).

From an interview with Tibergen, Cohen notes:

"A man recently asked him (Tinbergen) what were the rules when he observed, what was the grammar. And he (Tinbergen) found he could not answer. He compared the situation to a primitive tribe that can speak its language perfectly, but could not begin to analyse its grammar, the rules abstracted out of the way they speak. The same goes for observation. Good ethologists know how to do it but they cannot self consciously dissect how or why. 'You can't for example teach all pupils how to observe. You could almost say, either they have got it or they have not' (States Tinbergen). It surprises him too, how easy it is to miss things ........ observation is an individual thing, more individual perhaps than many life scientists would like to admit. It is ironic, too, how little study has been made of observation. Observing observation does sound a little like one of Russell's paradoxes, but it is not paradoxical at all.

(Interview with Tinbergen in "New Scientist" vol. 55 No. 804, July 13, 1972. P.93).

And there are strings attached too!

The following quotation explains these constraints clearly when referring to observation:

> "The difficulty of observation lies largely in unsuspected bias. People forever see what they <u>want</u> to see, or what they <u>ought</u> to see. It is extremely hard to rid oneself of such unconscious prejudice, and to see what actually <u>is</u> there, no more and, no less. Past experience,'common knowledge', and often teachers, can be subtle obstacles to correct observation, and even experienced scientists may not always avoid them."
>
> (Weisz 1967)

Thus, observation with regard to scientific work is not a simple straightforward business. Unless observation is directed towards certain specific functions as in the training of skills, and with the observer consciously rejecting any concomitant stimuli as irrelevant, the act of observation involves an appreciable cognitive input from the observer.

Such an argument, if accepted, would make the given example (Activity on The Bunsen Burner' see 4.1 p.52) appear as a training in the correct use of the Bunsen burner instead of being "Observations & Experiments" with a Bunsen burner. Therefore the guided-discovery or heuristic approach, especially if it is highly structured, tends to put the teaching of science into a straitjacket more akin to training than to science education. Despite the good intentions of the curriculum developers such a teaching technique permeates the structure of all the texts in M.I S.P with the exception of the activities in the Environmental Studies Section.

4.2 (a) HYPOTHESIS

Notwithstanding what the observer brings to the act of observation, what he gets out of it, i.e the learning outcome , is fundamental in science teaching. Now science education should emphazize both the process and product of science. Included in the process part is hypothesis making. This, in fact, forms the nucleus of any learning is science. Consequently hypothesis making or theorising is central to the teaching-learning interaction in science.

As Tinbergen said in his interview with Cohen:

> "We placed a tremendous emphasis upon observation. Observation is a creative act and we have been in danger of skipping the whole observational phase.

> When you observe, when we observe we are hypothesising all of the time. We think in terms of evolution, in terms of natural selection, for example".
>
> (New Scientist, Vol.55, No. 804, July 13, 1972:93)

Now the guided-discovery approach, by virtue of its rigidity due to its directed mode of teaching as exemplified in the M.I.S.P. texts, restricts hypothesis generation to a uni-modal learning outcome. This means that pupils are taught in such a way that their hypothesis is forced to zero in on existing scientific knowledge, what is called <u>public knowledge</u> by Polanyi (1966) as opposed to his concept of <u>tacit knowledge</u>. The latter, the pupil's own imaginings, are there but are not permitted to be brought out into the open for discussion and analysis.

Polanyi (1966:29), expanding on the nature of tacit knowledge, points out that:

> "there exist no explicit rules by which a scientific proposition can be obtained from observational data, and we must therefore accept also that no explicit rules can exist to decide whether to uphold or abandon any scientific proposition in face of any particular new observation".

This tacit knowledge, i.e personal knowledge, is learned by doing science rather than by acquiring rules for doing it. Polanyi (1966:43) further comments that:

> "School science imparts a facility in using scientific terms to indicate the established doctrine, the dead letter of science, while the University attempts to bring this knowledge to life and to perhaps impart a glimpse of true scientific life and judgement. A full initiation can only be gained by the gifted few, who through close personal association with a distinguished master, gain insights into the tacit workings of scientists".

The emphasis on the master-apprentice relationship together with the fact that assumptions underlying the process of scientific discovery and verification contain tacit elements, implies that scientific education is more by assimilation than by training or instruction.

This last point on assimilation brings into focus the question of theory-building in science. A theory can be regarded as an optical lens. There are as many sorts of lenses as there are theories. This follows from Polanyi's thesis of tacit knowledge.

Each individual observer generates his own tacit or personal knowledge from the act of observation. If objects are viewed through one lens, the objects that do come into view can be given the status of 'facthood' according to this theory. Another lens (theory) which, when applied to the same phenomena, may bring into focus other objects different from the first case, could also be accorded 'facthood'. This latter lens may blur the well demarcated objects of the first lens. Therefore some objects, observable through one theoretical lens, may not be observable through another.

A proviso must be incorporated at this stage. It will be noted that the term 'facthood' has been used. This is so, because it is logically not possible to observe facts:

> "We observe objects, processes and events. But facts must be a different kind of denotatum, logically different. We do not observe facts (what would they look like?). Facts are not objects, or collections of objects, or constellations of objects. Facts are <u>to the effect</u> that, e.g. a bee while supping a flower's nectar gathers pollen on its limbs, later deposits it on other plants thereby fertilising them. A statement to that effect would be true, or false,

in virtue of facts of this type - and not because of the simple existence of bees and flowers, and certainly not because such facts are bees and flowers or the geometrical interrelationships, or true statements about them. Facts are what true statements state.

(Hanson 1972)

Hanson further amplified the distinction between 'fact' and 'facthood' :

> "Noting the conceptual intimacy which obtains between 'the facts' and statements about the facts, however, suggests to other philosophers that there can be nothing logically less complicated about facts than about the statements themselves. Since statements are conceptually more intricate than names, so also facts must be conceptually more intricate than objects; more intricate than object clusters too."

The theory - laden character of 'the facts' soon comes to impress such thinkers even more forcibly than is the case with observation. For whatever is 'out there' that makes us say (truly) that the space immediately adjacent to our sun is non Euclidian, or that the symmetry properties obtaining within our universe indicate the existence of an anti-particle corresponding to each kind of familiar particle now known - these 'whatevers' must count as facts. Such 'whatevers' are accorded 'facthood' because they 'anchor' the least vulnerable statements within exact theoretical physics. <u>The philosophical tendency here, then, will be to construe 'the facts' as those objective organisations of the objects, events, and states of affairs within a scientific subject matter which render true the theories we hold.</u> The view thus arises that 'the facts' are those conditions a subject matter meets such that a given theory might be applied to it - the boundary conditions.

In that sense, 'the facts' are theoretically determined 'somewhat as the rules of chess determine what layout the chessboard must have at the onset, and what moves will be permissible therefrom so that the subsequent interchange could be describable as chess. Thus in a Wittgensteinian view: ..........
'the fact that it can be described by Newtonian mechanics asserts nothing about the world; but <u>this</u> asserts something, namely, that it can be described in that particular way in which as a matter of fact it is described'.

Possible science is thus a potential infinitude of possible theories - scientific idea games ..........

........... so taking ' cognizance of the facts ' is much more than simulating and emulating a hypersensitive data receptor. On the other hand it also seems to be more than just the clamping of a scientific theory's rules and definitions upon the world, thereby selecting <u>of</u> study only those subject matters which are co-operative with the exact theories. Rather the facts emerge as the world's possibilities for being described in some available language - which possibilities will be every bit as 'theory-laden' as the descriptions themselves are disclosed to be. (Could $E = Mc^2$ have been expressed as a fact one million years ago? For whom?). And this will be so whether these descriptions concern only simple colour registrations as in titrations, or indicate simple number assignments, as in most standard cases of measurement".

(Hanson 1972)

Phenomena are accorded 'facthood' only when they meet the conditions of a theory. If the phenomena do not meet the conditions of theory then it is difficult to see how such phenomena can be accorded 'facthood'. Facts therefore, are, to use Hanson's term "theory-laden".

Moreover, Hanson recognises the whole spectrum of theory from the 'Old Wives' Tale at the one extreme, to more or less permanent and stable theories at the other extreme. These permanent theories have been expressed as 'facts'.

Hanson does not discount the more 'de-facto' theories. A current 'Old Wives' Tale may, with time, bring into focus more and more clearly, sufficient phenomena to attain the status of reputable theory. Alternatively, what we hold to be respectable theories af present, may be treated with inffifference, or even laughed at a hundred years from now. (An example which immediately womes to mind is the change in theory relating to the post 'heart attack' care of patients. Physical exercise is now, but was not previously, an important aspect in the rehabilitation of coronary patients).

If facts are not theory-laden, how does one interpret findings? Does,one merely let the results 'speak for themselves'? Interpretation again presupposes a theoretical position. Koestler (1964) strongly criticises the'non-theoretical' position:

> "By stressing the importance of the <u>interpretation</u> (or reinterpretation) of facts, I may have given the impression of underestimating the importance of <u>collecting</u> facts, of having emphasised the value

of theory-making at the expense of the empirical
aspect of science - an unforgivable heresy in the
eyes of Positivists, Behaviourists, and other theo-
rists of the anti-theory school. Needless to say,
only a fool could belittle the importance of
observation and experiment - or wish to revert to
Aristotelian physics which was all speculation and
no experiment. But the collecting of data is a
discriminating activity, like the picking of flowers,
and unlike the action of/lawn-mower; and the selec- a
tion of flowers considered worth picking, as well
as their arrangement into a bouquet are ultimately
matters of personal taste. As T.H. Huxley has said
in an oft-quoted passage:

> "Those who refuse to go beyond fact rarely get as far as fact: and anyone who has studied the history of science knows that almost every step therein has been made by ....... the invention of a hypothesis which, though verifiable, often had little foundation to start with ........".

(Koestler 1964)

A stress upon facts makes science an intellectually rigorous subject. The more terms and meanings that a pupil knows and can use in essays, examinations and informal discussions, the more 'learned' he apparently is. The following quotation seems apt:

> "Perhaps the most common implicit rationalization, especially with regard to the teaching of science, is to put the notion that 'proper standards', 'intellectual rigour' can be preserved only by close adherence to facts. If it were true, it would be 'rigormortis'; but it is not true, and the presentation of theory or hypothesis as though it were fact constitutes a debauch of intellectual standards. No wonder so many students rebel against science teaching in this guise. The sheer 'learning up' of vast quantities of factual information is dreary enough in itself. On top of this the brighter students undoubtedly gain some inkling of the fraudulance of the whole business, and they cannot help but be disturbed and demoralised".
>
> (Stenhouse 1972)

Note the statement concerning the presentation of theory or hypothesis masquerading as fact. Now a theory is a possibility for describing the world. There may therefore be many possible theories, ranging from old wives' tales to theories which seem to be so resilient that they are accepted as fact. The important point is that though one particular theory may be important as a possibility for describing the world, it is still a possibility. At the risk of repetition, the lens analogy will again be given. The analogy that a theory is a lens seems to be appropriate. When applied to phenomena, one lens will 'bring into focus' particular aspects.

Another lens would 'bring into focus' other possible aspects. What comes into focus can be accorded fact-hood. Thus it is theory which determines what can be counted as fact. This has been emphasised in a number of accounts, notably Hanson (1961, 1967), Kuhn (1962) and Koestler (1964, 1967).

Hence, in conclusion, the incorporation of theory would reduce the quantity of facts to be learned (despite the 'knowledge' explosion'). It would also serve as a resilient 'tool for thinking'.

But science education does not seem to regard theoretical issues in science as sufficiently important. Such a stand does not augur well for science:

"The Committee suggests in several places that many able students are deterred by the rigour of school science, especially when that rigour degenerates into a grammarian's formalism, when it is bolstered by an inordinate bulk of experimental work, and when it is overlain by vast bodies of factual information".

(Thornton 1969)

A recent observation of science education in America also serves as a warning of possible consequences:

" "Science students are plainly 'turned off'. It may be, as Jean Mayer of Harvard claims, 'largely the result of the Balkanization of teaching. And it may be as Harvey Brooks suggests, a matter of failing to make non-science students socially literate (Harvey Brooks "Physics and Polity in Science" 1968). I am aware of the problems of specialization. I hear the complaints of my scientist colleagues that teaching both science and the social impact of science would impose an unbearable 'information overload'. I remain unimpressed".

(Krenzberg 1972)

A possible remedy has been clearly stated:

> "The remedy clearly, is for everyone to come to a a much better understanding of what scientific activity is really like. This is desperately urgent with regard to those who teach science at whatever level. A great deal of scientific research can quite usefully be done by people lacking an understanding of higher methodology - but such a lack in teachers of science generates in those taught the sort of fundamental misorientation, the unhappy results of which we are coming to see. Since virtually everyone undergoes formal training of some sort or another at the tertiary level, the immediate need is for changes in the education offered at that level".
>
> (Stenhouse 1971)

The implications for teacher-training must not be overlooked. A strategy must be devised to move teachers away from teaching as they were taught. This aspect will be taken up more fully later.

However, it is important to emphasise the usefulness of theorising and to show how much theorising eventually leads to scientific thinking, problem solving and decision making. The dichotomy between theorising and learning of facts will lead us to decide where to put the finger on in science education. Such a decision will set the directions for the effectiveness of science teaching.

4.2 (b) The Importance of Hypothesising

Questions commonly heard among members of the teaching profession are of the following sort: why should hypothesising be given a place of importance in education? Surely it is the job of science education to deal with 'facts' and the practical realities of hard bench research, as opposed to dealing with vague theories. Surely it is better to get down to the realities of science at introductory levels with emphasis upon practical skills and techniques, in contrast to armchair theorising. Yet, the problem of the indigestibility of information has to be overcome. This is where theory and comparisons derived from theory become important.

Curriculum text writers and curriculum makers seem not to have realized the importance of theorising in education. It appears that science education accepts the viewpoint that anything which is new is better. New curricula are purported to be 'improvements' over the old. This need not be the case.

For example, doubt has been cast on the value of the New Mathematics curricula and the P.S.S.C. Physics curricula have lost favour (Layton 1972). The text-book writers maintain a generally non theoretical position. This theory is the scientific method. It is given such support by these writers as to count as fact. But it has been noted previously that scientists do not necessarily apply ''the scientific method' in their research. (Medawar 1967). The method cannot therefore be regarded as a fact. Text writers, however, persist in incorporating this method into texts, and presenting it as though it were factual.

Moreover, if the method was so significant, it would mean that anyone who wished to learn the method could become a scientist. Clearly this is not so. Being familiar with the method does not make a great scientist. Indeed the converse may be true. It is the individuals who break from accepted methods and 'norms' who may become the great scientists.

(Kuhn 1962; Koestler 1964; Stenhouse 1971).

The 'information explosion' is probably a major reason why the'scientific method' is perpetuated. It seems that the 'scientific method' acts as an apparent organising core and unifying concept for all science. There might be enormous informational content, but there is still the method which holds all science together.

There is also another reason. Text writers and curriculum makers get the information for courses and texts from research journals. Because of the great proliferation of details in research journals, text writers are likely to consult either the abstracts or reviews of research. If they do this the risk of gleaning 'misinformation' is greater, because the context of the deriving of the research findings is not known. Some research findings are at best tentative. Text writers and curriculum makers transform these to 'facts'.

Furthermore, the way in which research is written up in a research journal is usually in accord with 'the scientific method'. But this may not be the actual sequence which the researcher carried out when he researched. Text writers and curriculum makers seem to assume, wrongly, that the research journal reflects the actual sequence of events of the laboratory or research activity. They assume that the steps outlined in the research papers are those which have been carefully followed by the researcher when he was doing the research. Yet there are a number of published accounts which show this not to be the case. Chance, hunch, and emotional aspects are all involved,but are never noted in research journals. Text writers do not allow for these aspects. Thus these writers in science education assume that 'the scientific method' outlined from research journals is the actual way in which the research progressed.

Despite the apparent order or steps in the publications what actually happened is quite different. Pantin (1968) says:

> "Now the actual order in which the experiments were done was quite different from this. The course of research shows quite clearly the importance of authority and contemporary fashion in directing one's attention to phenomena. It also shows the importance of the illative sense in reaching conclusions. It shows the importance of contemporary models and the importance of the aesthetic and emotional aspect in initiating research. Moreover the development of the work underlines the importance of chance - though the element of chance is that with which a scrumhalf is familiar rather than that of a winner in Premium Bonds".
>
> (Pantin 1968)

By 'illative' sense, Pantin means a

> "spontaneous divination by the mind that a conclusion is true, which uses every kind of information experience has given us, and which uses it in a way different from logical inference.

Research publications are less "illative" than the actual research. 'Illative' characteristics, chance, and emotion are consciously kept out of research publications.

A major intention of the text writer is to be able to transpose information to students in as simple and concise manner as possible. This has a number of consequences. Firstly, the tentative nature of hypotheses is neglected. That research is a progression of developing hypotheses and findings is neglected as complications.which could confuse students.

Secondly, the 'illative' sense is neglected in textbooks and research publications. It is assumed that actual research is mirrored in the way the research publication is presented. Biographical anecdotes are not considered. As a result, the 'scientific method' is implicitly given importance.

Therefore a substantial dose of hypothesising or theorising actually reinforces the 'scientific method' in action. Science has progressed through research being a progression of developing hypotheses and findings. Consequently, the learning of science in schools must leave the lion's share to pupils' efforts at hypothesis-making. Such a learning experience develops the pupils' scientific thinking. In briefest terms, this is the gathering, selection and use of evidence to arrive at and test generalizations. Each word can be expanded to list more detailed aspects, for example ways of gathering evidence include observation, measurement and experiment, but the brief statement is perhaps all that is necessary in this context to point out that we are defining a process. There is no doubt that familiarity with and a continual use of such a process will help the pupils in decision-making. Apart from its relevance in daily-life, decision-making has survival value and this is especially so in this era of impending nuclear holocaust. A general broad-based education, as advocated in the Project Document (U.N.D.P 1973), includes practice at decision-making in order to avert the dangers of producing a mass of uniform citizens who do not know how to think and to solve problems (see 1.2p.8 ). The germ of the development of an uncriticising community would be avoided, thereby wrecking the policies of social control and economic exploitation of dominant social or professional groups (Prithipaul 1976; Young 1971; see 1.1 p.1).

Science is now more frequently being viewed as a human activity, closely linked with social issues of responsibility and values. For example, at Ordinary level the Schools' Council Integrated Science Project (S.C.I.S.P) contains a unit entitled 'Science and Decision Making', while candidates taking Nuffield Advanced Chemistry are expected to be aware of a variety of social responsibilities.

Such trends as these are in line with recommendations made by various educational bodies, including the Association for Science Education (A.S.E) which in its eight page policy statement of 1971 made the general assertion that:

> "Scientific knowledge has been and is being accumulated over the years through processes of discovery which are the result of human endeavour. Science teaching should reflect this endeavour, and science should be presented in ways that show how its applications influence the patterns of modern life and social organisation".
>
> (A.S.E, 1971:3 "Science & General Education" (England).

Further on, the A.S.E (1971) policy statement stated:

> "It is among the functions of the science teacher ....

> to help pupils to undetstand the thinking of the scientist and to provide some knowledge of the kind of problems which are capable of solution by scientific means, thereby avoiding misconceptions prevalent among non-scientists today".

Moreover, the tentative nature of hypothesising is given support by Nelkin (1976)"

> "Perhaps the most difficult concept to convey to those who are not scientists is the delicate balance between certainty and doubt that is so essential to the scientific spirit. Textbooks in particular tend to convey a message of certainty to the non-specialist, for in the process of simplification, findings may become explanations, explanations may become axioms, and tentative judgements may become definitive conclusions. Few textbooks are careful to emphasize the distinction between fact and interpretation, or to suggest the intuition and speculation that actually guide the development of scientific theory.
>
> (Nelkin 1976: 218)

As a result, pupils gain an image of science education from schooling which is both mistaken and off-putting. This point has been raised by Bullock (1976), Bondi (1975) and Layton (1973). In Bondi's terms pupils are presented with a false prospectus.

Progress in science requires scientists with imagination and vision. This does not refer only to the relatively few minds capable of originality and innovation, but applies also to the bulk of the scientific community whose minds need to be open to new and challenging ideas. It falls to a science education to foster such imagination. There is evidence that we are failing to make sure that it does so, or at best we are failing to include imagination sufficiently in the image of science presented to young people. In consequence those who have and value imagination are discouraged from continuing with science; and many a potentially inspired scientist has been prevented from gaining even the rudimentary insights into what he or she would have found to be an exciting,challenging and fulfilling career. We are all the poorer without the contribution of such lost talent.

An example will illustrate the above argument succintly. Consider the case of the boy who attributed the acceleration of a falling body to its having a greater weight of air above it

as it gets nearer to the ground (and refused to accept that this was disproved by all the usual school experiments including The Guinea and The Feather) may well be showing more of the talent we wish to encourage than one who uncritically draws the "correct" inferences from a sequence of experiments carefully chosen to make them unavoidable.
(as given in M.I'S.P Book I Theme 5: 78-80).

Bondi (1975) made the point thus:

> "That science is so utterly human that it is based on the very concept of fallibility - that is terribly important. But how many school children can ever appreciate this?"

Bullock (1976) too would want to move away from the dehumanised image of science, and to establish a view of science which includes imagination and compassion as well as observation and analysis. In many ways these are ideas which have had some effect on science education already. There are three aspects to the argument. Science is an utterly human activity. Everything in science depends on theoretical contracts which are of human manufacture and which change from time to time. This process comes about through the interaction of mind on mind, making science a social act dependent on communication. Bronowski (1970) made the point when he wrote:

> "The society of scientists is more important than their discussions. What science has to teach us here is not its techniques, but its spirit, the irresistible urge to explore".

However human the nature of science, the humanity has not always been recognised by those outside science. Medawar (1963) attributes this to the fraudulent means of communicating used in the scientific paper. The important point to emphasise in Medawar's work is that when communicating his work formally the scientist does not attempt to reconstruct the process but to recast it into a mould which gives a false representation of what went into it, and consequently a false prospectus of the life of a scientist.

This recasting for communication is a problem familiar to the teacher. Pedagogy also demands a recasting of knowledge. As well as learning the science, the pupil is also learning the skills and attitudes associated with the process of becoming and finally being a scientist. There are interactions between newly received knowledge and previously acquired knowledge and the knowledge-getting process itself. As he or she comes to know more, the pupil has to be constantly reconstructing what is already known. The pupils have to do this themselves; but it is a mistake to take this to mean that they are necessarily doing for themselves and in their own way. Pupils receive knowledge in the context of the teacher's overview, and more often than not the pupils' successive adaptations of the structure of the subject is a progressive approximation to the teachers' or the textbook's categories. In a letter to Physics Education, Sparke (1974) describes the textbook presentation of science as being designed to achieve clarity, ease of reference and a simple-to-remember structure. This he calls the 'logical approach', and goes on to say "the trouble with the logical approach is that it hides the very nature of scientific theory it is attempting to describe". Certainly it hides the humanity of the scientist.

Layton (1973) recognises the problem in this way:

> "But from the standpoint of general education ... the very steps which have increased the power of science as a mode of intellectual inquiry have generated formidable problems associated with its teaching and learning".

He attributes the restricted contribution science has made to general education to the development of a curriculum based on an internalist view of science. Science teaching has moved away from an authoritarian presentation of a body of knowledge; but although giving greater emphasis to science as a process of establishing knowledge while it remains a study of science as an end in itself, it remains educationally no longer defensible. By concentrating our efforts on improving our methods of teaching science, we have lost sight of the educational value of what we are doing.

Therefore, hypothesising on the part of the pupils is a very important factor in their general education. All the 3 domains, cognitive (thinking, decision-making), affective (emotions), and psychomotor (practical work in science) partake in this educational process. As it is sometimes said, it is better to travel than to arrive (the means are more interesting than the ends!). The "scientific method" will be the richer for that.

## 4.3 EXISTING SCIENTIFIC KNOWLEDGE

Text writers often for reasons of expediency and clarification make apparently descriptive statements act as cloaks for prescriptions. But to present a prescription as a description is to give the prescription a degree of 'factuality', and few people, students, or teachers implementing curricula, dare to argue with 'facts' (Stenhouse 1972). The acceptance of tentative findings <u>as though they are facts</u> is termed 'factualism'.

A perhaps statement is written into a text or a curriculum as an 'it is' statement. The student can then learn it as a fact. The transformation of prescriptions is another source of the general condition of 'factualism' currently being emphasised in sciense education.

> "If a prescriptinn is put forward openly, people may diasagree with it. There is a healthy streak of 'contrariness in most of us. If it is put forward as though it were a descriptive statement of fact, however, most of the 'contra' reaction is inhibited. Nobody wants to look as though he is arguing against the facts".
>
> (Stenhouse 1972)

On the other hand, theory and theoretical issues in science would promote 'contra' viewpoints. But present textbooks and curricula do not allow for this. One reason is that of expediency. Description (and even the rigidly structured guided discovery mode of teaching) is easier to present in a text or curriculum than to have a long complicated type of discussion with many provisos about theoretical issues. It is also more expedient for a teacher to teach 'facts' with crammed class programmes. Preparation needed for theoretical lessons and discussions would take longer and be more intricate, than the preparation necessary to present facts by didactic exposition, practical work or demonstration.

As Stenhouse (1971) says:

> "It saves trouble if theories and hypotheses are presented as facts. Nobody is then tempted to argue against them. The time and temper of the teacher is saved. The fact that under this sort of regime, education has degenerated into mis-education is either not noticed or else is 'explained away' by some facile rationalisation".
>
> (Stenhouse 1971)

The general situation at present in science teaching is to stress experiment and fact, as opposed to observation and theory. For instance, Brian (1968) states:

> "Science teaching nowadays in too many schools, is rather too factual, too dull, and not obviously relevant to human and social affairs. Young people get a mental picture of science as a rather arid and not really challenging subject.
>
> (Brian 1968)

Far from creating interest, such an emphasis on the acquisition of facts may have long-term consequences:

> "One of the valuable discoveries which the Dainton Committee has to report is that students following science tend to be looked after by well qualified teachers. The question now is who should tell these talented people <u>that they must spend less time behaving as if they were teaching in Universities.</u>
>
> (Editorial in "Nature" Vol.217, March 21, 1968:792)

Teachers in science appear to have difficulty in breaking from the ways they themselves were taught at school. Yet there is a need to break away from such a situation, i.e teachers teaching as they were taught and pupils bent on learning facts. Maybe there will be no 'drift' from science in developing countries in the near future since science is, perhaps, mistakenly associated too closely with technology; what is more urgent is to generate a 'drift' toward science as, otherwise, a great deal of talent will lie fallow. Therefore, for science education to provide a general broad-based education, emphasis must be more on theorising and less on learning of facts.

The following quotations illustrate these points clearly:

> "Undergraduate education in science comes after a long and varied exposure to science and mathematics in primary and secondary school. The quality of this earlier encounter is probably the most decisive factor in determining attitudes and motivations of students for further science study and in generating the sustained generation that a career in science so aften requires. It is typical of the state of educational research that little effort is being-made to evaluate this experience".
>
> (Doty and Hindberg 1972)

> "Psychological, motivational, economic and sociological factors work together over a period of several years to predispose an individual towards a particular type of occupation, while his opportunities in other directions become limited by his education".
>
> (Nature, Vol.217, March 23, 1968)

Note the references to quality and limitation of a pupil's education.

M.I.S.P has hatched an Integrated Science course which is one of the 5 core subjects to be studied at the lower secondary school level. As it is a compulsory course, does it follow that it can be unattractive and uninteresting?

Mc Pherson (1968) puts the dilemma succintly when he states:

> "If science were compulsory, it must be attractive; if not attractive, it will suffer if made compulsory; and if it were attractive it would not need to be compulsory".

Even where efforts are made to reduce the factual content, the emphasis can still be misdirected. Theory may be taken to mean that which opposes the practical. Current curriculum makers imply this when they make statements of the following sort:

> "The intention was rather to keep the volume of factual and theoretical material to a minimum .... Throughout the course, great emphasis is placed on practical work and on the development of associated skills".

(Senior Biology Revision Project, N.Z Curriculum Development Unit, Department of Education 1970).

Some text writers and curriculum makers react to the problem of overfactual content by claiming to emphasise 'themes' or principles and processes instead of masses of detail. Others develop programmed learning type texts, as in M.I.S.P. (Smallwood and Green 1968). Or "enquiry processes" (Bruner 1960) are stressed in science education. But the problem of the 'knowledge explosion' still remains:

> "The expansion of teaching courses need to be proportional to the 'knowledge explosion' only if their purpose is the mere inculcation of factual information, Everyone pays lip service of course, to the notion that teaching leads to 'understanding principles' rather than 'knowing facts' - but in practice the teaching of science despite all recent advances, the 'discovery' method, the 'activity' approach, and so

on remains largely a matter of imparting factual information. Or rather, information is imparted as though it were factual, when much of it really is not".

(Stenhouse 1972)

The lip service paid to 'enquiry processes' is well exemplified with the following statements taken from the Introduction of M.I.S.P. Book I or Book II:

> "It (the prescription) places great emphasis on the Development of knowledge and Understanding, Skills and Attitudes.
>
> Under knowledge and Understanding appears " The Recall of essential facts and concepts" at the top of the list of priorities of learning outcomes".

It will be noted that what has to be recalled is <u>everything</u> which may be taught in the science course. The 'concepts' and 'principles' are all implicitly given the properties of facthood to be remembered. The temptation is great and even unbearable due to pressure of examinations to short-circuit the "enquiry processes" and revert to didactic exposition. No doubt, this is what occurred in many schools using M.I.S.P texts (see Chung 1977: 27-30).

The didactic teaching approach presupposes an implicit faith in the teacher as an authority giving pupils the impression that there is little unknown in Science. As Koestler (1964) and Hudson (1968) put it:

> "In the symbolic year of 1899 the foremost German biologist Ernst Haeckel published a best selling book "The Riddles of the Universe" which became the bible of my youth. Haeckel was the first propagandist of Darwin in Germany, and the first to draw up a genealogical tree of various orders of animals. Like Spencer and Huxley in England, he was a typical representative of the buoyant and arrogant optimism of the nineteenth century. His book enumerated seven Great Riddles of the Universe of which six were 'definitely solved' - including the Structure of Matter and the Origin of Life; the seventh was man's experience of freedom from choice. However this was not really a riddle but a 'pure dogma' based on an illusion having no real existence - so there were no more riddles left".
>
> (Koestler 1964)

> "Both at school and at University, this confrontation with intellectual authority is especially acute. It

is made apparent to each of us, not through the malign motives of our teachers, but from the force of our own ignorance, that if we want to succeed, our best course is to do what our teachers and examiners expect of us. For this reason, there exists a strong temptation not only to accept all authoritative judgements as given, but to accept the horizons of school and university syllabuses as the boundaries of all sensible enquiry. The massive largely unavoidable insistance on authoritative knowledge faces the student with an unenviable choice: that of knuckling under and being right; or of being individualistic, self sufficient and wrong".

(Hudson 1968)

Theoretical outlines can therefore map out unknown ground. If students in science are discussing great inventors, and discussion comes round to likely inventions in the future, they commonly reply that there is very little else to be invented. Their generation will never invent anything - it was easier for Faraday, Pasteur, Marconi and Bell, because the circumstances were right and science was on an upsurge. Invention and discovery always look as though the process was simple in an historical context. However, it would seem that a general lack of theory in all science has contributed to this frustrating situation. It all seems known:

> "There is little curiosity about science;
> so much is now established fact".
>
> (A student's comment, Potts 1968).

Current text writers in stressing what is known also emphasise authoritarianism (Hudson 1968). Students in science education must submit to the authority of the text-book and to the 'facts' therein. Theoretical notions, if incorporated, would encourage discussion and argument, thereby reducing authoritarianism in science education. Much doubtful and dubious information could be harboured under a shield of authoritarianism - the stronger the authoritarianism, the greater the likelihood of their doubtful information. If this was so, science could develop into a cult. Science would change to 'scientism' and dogma would prevail (Frankl 1969).

At present with emphasis upon the authority of fact, 'what is known' is being cultivated at the expense of 'what is not known'. And generations of pupils are learning what others before them have learnt. Ignorance is not given emphasis in current texts, courses or curricula. A science, to be vigorous, must show that it is tackling little known areas. This is surely a way of advancing the state of scientific knowledge. At present this does not seem to be the case. If it were, a great deal of emphasis would be placed upon theoretical discussion in introductory science education.

Yet current science education takes a 'backward' stance, emphasising past achievements, some of which masquerade under an enigma of finality. (Stenhouse 1972). A return to a 'forward' looking stance seems necessary.

Tinbergen sets the problem when he refers to the publications of Morris (1967) and Lorens (1966):

> "As examples I select Konrad Lorens's book 'On Agression' and 'The Naked Ape' by Desmond Morris. Both books were best-sellers from the start. Ethologists are naturally delighted by this sign of rapid growth of interest in our science (even though the growing pains are at times a little hard to endure). But at the same time we are apprehensive, or at least I am.
>
> We are delighted because, from the enormous sales of these and other such books, it is evident that the

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mental block against self scrutiny is weakening - that there are masses of people who, so to speak, want to be shaken up. But I am apprehensive because these books each admirable in its own way, are being misread. Very few readers give the authors the benefit of the doubt. Far too many readers either accept uncritically all that the authors say or equally uncritically reject it all. I believe this is because both Lorens and Morris emphasise our knowledge rather than our ignorance, (and in addition present as knowledge a set of statements which are after all no more than likely guesses). In themselves brilliant, these books would stiffen, at a new level, the attitude of certainty, while we need a sense of doubt and wonder, and an urge to investigate, to inquire".

(Tinbergen 1968)

## 4.4 EXPERIMENTAL VERIFICATION

Curriculum makers, text writers and many teachers hold that 'experiment' is important for science to improve. For example, the detail devoted to experimentation in texts such as M.I.S.P and others seems to indicate that 'experiment' is actually the most important aspect of science. However it is necessary to highlight some of the characteristics of an 'experiment' in the context of science education.

Firstly, 'experiment' may mean any practical exercise which involves laboratory equipment. Secondly, it may involve the simplification of phenomena to a single experimental variable which can be used against a 'control experiment' to test an hypothesis. The 'principle of parsimony' is applied where complex reality is pared down to its barest essentials. This can be labelled the 'classic' meaning of 'experiment', outlined for example in Otto and Towle (1969) and in Villee (1967). This particular interpretation is usually the one incorporated into discussion of the 'scientific method'.

Thirdly, in the educational context, 'experiment' may mean 'doing original practical work'. This could involve applying the classical experimental procedure, or any other procedure, to any investigation. In this case, the student would be acting as a scientist doing research work. The situation where the student is an actual scientist has been outlined (Ausubel 1965).

Fourthly, a 'field exercise' may be labelled 'experimental'. Usually the exercise involves data collection, and empirical procedures.

Fifthly, 'experiment' is made use of to help students acquire practical skills. Being acquainted with apparatus is important for all science students. Skill in the use of everyday basic techniques must be incorporated into courses and curricula. But once a skill has been developed to an acceptable degree, there seems little need to continue with repetition of the same skill, especially when time is at a premium. Yet many practical exercises belabour the obvious and involve repetitive use of the same skill for a number of exercises. This claim can be justified, because many of the exercises involve a scientific principle, very obvious to students, which could be presented to them formally. There seems little need to impede the comprehension of a simple principle by having to spend a great deal of time upon strict obedience to a set of instructions in a practical manual using already well accomplished laboratory skills.

As Thornton (1969) says):

> "The Committee suggested in several places that many able students are deterred by the rigour of school science especially when that rigour degenerates into a grammarian's formalism when it is bolstered by an inordinate bulk experimental work and when it is overlain with vast bodies of factual information".
>
> (Thornton 1969)

Nevertheless, 'experiment' forms an important and integral part of the 'scientific method'. This method is promoted in many text-books. It seems that it is the only way in which hypotheses can be refuted or confirmed. (Weisz 1967). Also, the findings confirmed by 'experiment' are thought to be more real than findings derived from 'mere' observation. Experimental operations are apparently meant to ascertain the reality of any given situation 'truthfully' and 'objectively'.

> "A hypothesis must be subject to some sort of experimental test - it must make a prediction which can be verified in some way - or it is mere speculation".
>
> (Villee 1967)

"Experimentation can provide the necessary evidence, and whosoever then experiments after guessing at answers becomes truly 'scientific' in his approach, be he professional scientist or not".

(Weisz 1967)

" The scientist must set up an experiment in which the hypothesis will either be supported or contradicted. While it is often difficult to do, all factors except the one to be tested, must be removed or accounted for. We refer to this one factor as the single variable or experimental factor".

(Otto and Towle 1969)

Finally Hanson (1971) puts the position strikingly:

"Thus the major function of the <u>scientific</u> enterprise - to wit, the attainment of <u>theoretical</u> understanding of knowledge - should be hampered as little as possible by laboratory 'busy work'. Refinements in conduitry and circuitry, in beam-focusing, in spectrometry, thermometry, and hydrometry - these may lead to more decimal places as one reports the results of measurements, but they rarely determine a new form for an equation or a new kind of inference concerning old subject matter".

(Hanson 1971)

Hence, in any curriculum development work in science, the curriculum developer must bear in mind the needs of the clientale in relation to science education and then choose the appropriate laboratory procedure to meet these needs. For instance, is the practical work to be used to give a broad based education through the learning of science or is it to be used for specialization in some fields of science and/or technology? Such a strategy will enliven the study of science by making it more interesting, more useful and more relevant. So experimentation has a very important role to play in the teaching of science provided its functions are clearly understood and implemented.

## 4.5 CONCLUSION

This part, as given in the M.I.S.P. frame of reference for the scientific method, is supposed to represent "Now I know a little more" after the study of a topic in science. Such an outlook, though enquiry processes may have been used, also interprets learning from a behaviouristic framework. (Mowrer 1960; Koestler 1964). Now behaviouristic principles are frowned upon in certain quarters:

> "We are constantly assured that the crudely mechanistic nineteenth century conceptions in biology, medicine and psychology are dead, and yet one constantly comes up against them in the columns of text-books and technical journals and in lecture rooms. In all this, Behaviourist psychology occupies a strategic key position. This is the case, not only in the United States where the Watson - Hull - Skinner tradition is still immensely powerful and keeps an invisible stranglehold (by negative reinforcements) on academic psychology. In England Behaviourism has entered into an alliance with logical positivism and linguistic philosophy".
>
> (Koestler 1967)

In stressing Behaviourism, science educators seem to avoid the issue that learning has essentially biological roots. A major reorientation in their pedagogical emphases would have coincided with the renewed current interest in the Biological nature of man, and how he behaves. (Tinbergen 1963, 1968; Hinde 1966; Lorenz 1966; Morris 1967, 1969; Fletcher 1968; Bronfenbrener 1968; Bowlby 1971; Stenhouse 1973). Surprisingly, curriculum makers do not seem to be aware of the research findings, and the methods and rationale (theory) of ethology, as it related to learning in man. Introductions to courses - 'aims and objectives' - maintain that learning has occured when the desired responses (aims) are seen to be acquired

Learning in this context is a set of responses which are previously determined by the appropriate external environmental conditions. These introductions imply this when they give specific details as to the exact types of desired attainable responses. A laboratory manual states:

> "Only by experience in the laboratory is it possible to see what science really is. No matter how much you learn about the facts of science, you will never quite understand that what makes science the force it is in history, or scientists the kind of people they are, until you have participated in such an experience".
>
> (Biological Science: Processes and Patterns", Laboratory Manual, 1970 Pages VII - VIII).

Apparently, the aims which are given in detail, and subsumed under enquiry processes, can be 'stamped in' during lessons and laboratory sessions. This assumes that the students are organisms who are passive receivers of stimuli from the external environment. This particular assumption is behaviouristic. Copies of external reality are taken in. A stimulus is applied to engender an appropriate response. It is the stimulus (the external environment) which is important. It must have certain properties to elicit an appropriate response. Apparently the 'aims and objectives' supplied in these publications are sufficient and adequate responses. The behaviouristic approaches to education are outlined in any current educational texts, and in Hull (1943), Skinner (1957), Koestler (1964,1967), and Fletcher (1968). The position which incorporates behaviourism as being the only means to learning is sometimes labelled 'learning theory' (Koestler 1964; Mowrer 1960).

By contrast the subject matter of ethology has shown that learning is an activity which has endogenous origins. (Thorpe 1963; Koestler 1964; Fletcher 1968; Stenhouse 1973). That is, an organism reacts to an environment. Organisms are not passive receivers of stimuli. Insight is involved. "Learning theory" does not appear to accept endogenous origins. It prefers to stress the importance of the external conditions as a pre-requisite for learning.

Piaget and Inhelder (Koestler 1969) have outlined this position as follows:

> "Empiricism has engendered many different ideas from naive concepts of knowledge as a copy of reality, to the more refined forms of 'functional copy' (Hull's behaviourism) to logical positivism which aims at reducing knowledge exclusively to physical experience and to language. If we look for common factors in these diverse approaches we find a central idea. The function of cognitive mechanisms is to submit to reality, copying its features as closely as possible, so that they may produce a reproduction which differs little from external reality. This idea of empiricism implies that reality can be reduced to its observable features, and that knowledge must limit itself to transcribing these features".

Current science curricula seem to assume that if the right external conditions are supplied, then what is learned will be an exact (and correct) copy of external reality. Piaget and Inhelder continue:

> " - such a concept meets with three fundamental difficulties. Biologists have shown that the

relationship between an organism and its environment ... is one of constant interaction. The view that the organism submits passively to the influence of its environment has become untenable. How then can man as a 'knower' be simply a faithful recorder of outside events? In the second place among fields of human knowledge and endeavour, mathematics for one, clearly escapes from the constraints of outer reality. This discipline deals essentially with unobservable features and with cognitive constructions in the literal sense of the word. Thirdly, man acts on, and modifies reality, he obtains by transforming his world, deeper understanding than reproductions or copies of reality could ever provide ......".

".... the exact counterpart of behaviourist empiricism in biological theory is a doctrine long since abandoned by biology itself, not because it was wrong in what it maintained, but because it ignored all that has since proved essential to an understanding of the relations between the organism and its environment; we are referring to the Lamarckian theory of variation and evolution. Soon after Hume had sought the explanation of the phenomena of the mind, in the mechanisms of habit and association, Lamarck too, saw the key to the morphogenetical variations of the organism and of organ-formation in the habits adopted under the influence of the environment. Admittedly, he was also speaking of a factor of organization, but he thought of it as a capability of association, not of composition, and the essential aspect of acquisitions was for him the way in which living things received, in modifying their habits, the imprint of the external milieu"....

"But Lamarck's theory lacks the basic principles of an endogenous possibility of mutation and recombination, and above all those of an active capacity for self-regulation. When Waddington or Dobzansky today put forward the pheno-type as a 'response' of the genetic pool to environmental 'incitements' this response does not mean that the organism has simply been marked by an external action, but that there has been interaction in the full sense of the term i.e. that as a result of a tension or imbalance provoked by environmental changes, the organism has invented an original solution by means of recombinations, resulting in a new equilibrium. Thus, when we compare this concept of 'response' to that used so long by behaviourism in its famous stimulus - response schema (S-R) we are amazed to find that the behaviourist psychologists have retained a strictly Lamarckian outlook, as if they had ignored the contemporary biological revolution.

In the exclusively Lamarckian context of behaviourist theory, the response is simply a sort of 'functional copy' (Hull) of the stimuli in their particular succession. Consequently, the fundamental process of acquisition of knowledge is considered a learning process in the empiricist sense of obtaining information through observation of the environment. If this were true, mental development as a whole would then be thought of as the result of an uninterrupted series of bits of learning in the above-mentioned sense. If, on the contrary, the basic point of giving certain responses i.e the 'competence', learning would not be the same at different development levels, and would depend essentially upon the evolution of 'competence'. The true problem would then be to explain their development, and for this the concept of learning in the classical sense of the term would be inadequate. In our opinion,we cannot but follow the principles discovered by contemporary biology. This means a fundamental change in the psychological interpretation of mental development".

(Piaget and Inhelder in Koestler 1969).

Science curricula seem to portray two assumptions which are important in this respect. The points subsumed under 'aims and objectives', 'recall', 'use of enquiry processes', 'use of practical techniques', 'interpreting data', all seem to be presented in a manner which is apparently obvious and 'pure', and can be immediately stamped into the cognitive apparatus. Secondly, the position which assumes 'pure' experience is well examplified with laboratory exercises. The culmination of the exercises usually involves a simple observation of colour changes, of obvious movements; (Observation has been cut down to a level where all who have basic sensibilities can observe). Apparently this paring away of complexity allows for exact copies (colour changes, movement) to be taken in as stimuli which are completely 'unbiassed' and hence 'truthful'. Madawar (1967) notes that observation is not unbiassed; Tinbergen (1972) also notes this.

Yet curriculum makers accept the Lamarckian view that 'exact copies of reality' are taken as functional copies. That is, presentation of aims and objectives, 'obedience' science and laboratory manuals advocate those aspects of external reality which can be simplified and then 'stamped into' the students, as though external realities can be internalised as copies.

By acknowledging ethological theory, curriculum makers would probably make major contributions to education as a whole, through giving learning a biological bias rather than a behaviouristic bias. In that sense, the 'Now I know a little more' conclusion following a science study would be nearer to the tacit knowledge parameter than to the public knowledge one. If this inference is correct, then the scientific method is an umbrella under which a game is being played with the utmost seriousness according to certain rules or steps but the game itself is as fluid as ever. This game is the study of science. To keep the game alive and on-going, the players (scientists) need to have abilities covering the whole spectrum of talent. There is no one scientific type.

> "Scientists are people of very dissimilar temperaments doing different things in very different ways. Among scientists are collectors, classifiers and compulsive tidiers up; many are detectives by temperament and many are explorers; some are artists and other artisans. There are poet-scientists, and philosopher-scientists, and even a few mystics. What sort of mind can all these people be supposed to have in common?
>
> (Medawar 1967)

Although a scientific activity involves both the process and the product of science (the means and the ends), the process is the more important component. In the product component, tacit knowledge predominates over public knowledge since consensus is more of an imposition than anything else. The process part generally can give rise to scientific thinking by learning through science rather than by learning science. For example, Columbus could be regarded as taking on the activity of an innovative scientist - he created in his mind an unknown by disobeying or negating currently established and accepted patterns. The initial negation phase at first begins at abstract theoretical levels:

> "The established paradigm in such a case, must be dethroned before the new facts can come to notice. In terms of logic, then, this means that the previous paradigm must - provisionally at least - be negated or held in abeyance .....
>
> The logical structure of the situation may be illustrated by reference to the popular (though quite erroneous) version of the discovery of America by Columbus. According to this story, Columbus was a brave pioneer who sailed westward across the Atlantic 'into the unknown'! The point which must be kept in mind is that so far as Columbus' contemporaries were concerned, he was <u>not</u> sailing 'into

> the unknown'. He was sailing into the known. They knew very well what would happen to him: he would sail on until he reached the edge of the world, and then he and his ships would fall over the edge and be destroyed!
>
> In short Columbus had to create an unknown before he could sail it on a voyage of discovery. To do so he had to negate the currently accepted 'known'.
>
> (Stenhouse 1971)

Indeed initial 'negation' of accepted rules may be an important feature for science. A scientific activity therefore is to hold in abeyance, or to negate currently accepted views, to attempt to create an unknown, and then to explore the ramifications of this unknown. If logic is also involved, then theoretical and philosophical notions are crucial to the process. Initial impetus in the 'braking of new ground' in science is obtained firstly at a theoretical level. This may involve breaking away from conformist thinking in science. It would seem therefore that it is better to develop a logically based theoretical position and conduct scientific activity on this basis, than it is to maintain an apparent non theoretical position. Hence theorising is an essential constituent of scientific activity. It leads to critical thinking and contributes to scientific literacy. Consequently, the 'Now I know a little more' conclusion should be directed more towards the means to acquire knowledge rather than towards acquiring the knowledge itself. Knowing HOW is much more useful than knowing WHAT.

# CHAPTER 5

## PROPOSED CHANGES FOR M.I.S.P.

Having discussed at length the shortcomings apparent in the scientific method as advocated for M.I.S.P, this chapter is going to look at changes that can be made to bring this method into line with the spirit of scientific investigation. While doing so, other concomitant problems will be dealt with as they crop up.

### 5.1 A Modified Guided Discovery Approach

Referring again to the experiment with the Bunsen burner in THEME I of M.I.S.P Book I (here see Chapter 4: 52-53), the instructions for this experiment can be given as follows:

> "You are to learn how to use a Bunsen burner correctly by opening the gas tap and lighting the gas issuing through the top of the burner. Take care not to let the gas spread in the room.
>
> The ring round the hole at the bottom of the bunsen is movable. The gauze can be used to test how hot the flame is.
>
> Carefully observe the flames you obtain. Draw labelled diagrams. Explain these changes".

The pupils are thus given freedom to investigate by trial and error. Observations and hypothesising follow. Possibility is given to the pupils to discuss their findings and to write out, in their own words, their observations, thoughts and conclusion. In this way, the pupils can experience science in action rather than carry out mechanically, as in a cookbook, the instructions for the practical work. Tacit knowledge provided with an opportunity to express itself openly here before the teacher, in discussion with the class, works towards a consensus called public knowledge (see 4.2 (a) p.64). With this teaching approach, the constituents of the scientific method are brought into play. Observations, hypothesising, experimentation, conclusion, not necessarily in the order given are all brought to bear on the investigation at hand. The cognitive, affective and psychomotor domains of the pupil partake in the work. (Bloom 1956). The illative sense may not be absent either (see p.80). Although the scientific method has been used, it has not been constrained within the logical sequence of science research reports outlined by Medawar(1967).

Whereas in M.I.S.P, the pupils are required to answer questions by Yes/No or naming the colour of the flame or giving very brief answers, the proposed teaching-learning approach enables them to participate by talking and writing. These functions of talking and writing are to be used as means by which the learner can make sense of the world. Teachers too often treat talking and writing solely as a medium of exchange and thereby fail to exploit their potentiality as instruments for interpreting the world. Bruner (1966) puts it succintly:

> "Language .... ends by being not only the medium of exhange but the instrument the learner can use himself in bringing order into the environment".
>
> (Bruner 1966)

The purpose here is to focus attention upon the functioning of language as an instrument of understanding: this can be done more readily when the focus of attention has been provided by a teacher (or the text) but the cognitive strategies for approaching the topic are under the learners' control. As an example, here is a talk between two ten-year-old boys, who are observing falling drops of water, and discussing their own attempts to draw the shapes of the drops.

Pupil 1 : Would you say that's the size of that drop?

Pupil 2 : Yes

Pupil 1 : Now we have to find out what shape it is as it drops.

Pupil 2 : You'll never find out ... It's impossible, see.

Pupil 1 : It isn't impossible. Get a movie camera on it.

Pupil 2 : It's something in the region of round with a point at that side.

Pupil 1 : If it is, and that's going down like that, that will probably catch up with that ..... and so it would be more round.

Pupil 2 : It's like that ..... when it's dropping.

Pupil 1 : It's getting straighter

Pupil 2 : It's getting rounder, I think

Pupil 1 : It'll be more round as the air pushed up, won't it?

(Barnes 1977: 141).

They are organising their understanding rationally through talk by using language to give outward form to their own thinking. There is no mistaking the reshaping of thought which is going on in utterances such as: "If it is, and that's going round like that, that will probably catch up with that ..... and so it would be more round."

Caught in this transcription we have the epitome of exploratory talk in which the speaker reflects upon and improves his own thinking in the process of putting it into words, partly for someone else but (perhaps more importantly) also for himself. The purpose of the task which their science teacher gave was to explore ways of representing the changing shapes which the boys observed, and both drawing and talking played their part in this. Thus it would be inappropriate to value this talk as if it were merely an unsuccessful attempt at a formal statement: its function is different. It is precisely the incompleteness, the inconsistencies, and the groping to interrelate and make sense that I am putting forward as a reason for valuing such talk. These characteristics are essential to its exploratory function; exploratory talk is not merely an inferior substitute for dogmatic assertion, but a heuristic tool in its own right.

This exploratory talk is a far cry from the short answers required for M.I.S.P texts. The Bullock Committee's report (1975) places a similar emphasis upon the functions of talking and writing in learning, and relates this to the learner's problem of coming to terms with the unfamiliar frame of reference used by his teacher. "What the teacher has in mind may well be the desirable destination of a thinking process; but a learner needs to trace the steps from the familiar to the new, from the fact or idea he possesses to that which he is to acquire. In other words the learner has to make a journey in thought for himself". (Bullock 1975). When a child writes or talks in an exploratory manner he is trying to relate to what he knows already some new observation or unfamiliar way of looking at things. And he is thinking all the time! Does not this technique help to minimize the dangers of producing a mass of uniform citizens who do not know how to think and to solve problems? (see p.8)

How far is children's ability in this way of making sense of the world utilised in classrooms and laboratories? If one looks closely at a typical sequence from a lesson (examplified by many of the Activities in the M.I.S.P texts), it will appear that those abilities which have been illustrated above are seldom called upon in class teaching.
For example:

Teacher : What was there in the bottom of the tin?
Pupil : Holes
Teacher : And?
Pupil : Big ones and small ones
Teacher : Right. A large hole that lets the gas in, and three small ones .... Pat, what's going in those small holes?
Pat : Air

Teacher : Air, right .... Now, what have we got in the can now, David?

David : Gas

Teacher : And?

David : Air

Teacher : How would you expect those two to be mixed? Would you expect there to be a layer of gas and a larger of air, or what?

David : Mixed .....

Such a pattern of question-answer-evaluation is of course typical of teacher-class dialogue. The woman teacher's strategy is first directed towards isolating and making explicit those aspects of the phenomenon that she wishes her pupils to attend to, the holes in the can, and its contents. Then she goes on to ask for a hypothesis about the state of the contents. Later, after the demonstration, she will use similar questioning to isolate aspects of what happened, and to elicit explanations. Although this teacher works through questions, her purpose is to present to her pupils a model of how this phenomenon is to be perceived and explained. She constructs the verbal patterns; all the pupils have to do is to follow, as the predominance of short answers indicates. At no point does a pupil construct a meaning at length: even the hypothesis at the end becomes the single word "mixed", already offered by the teacher. The experiment with the Bunsen burner follows the same pattern of question-answer-evaluation but this time, the teacher-class interaction is written as well as spoken. As explained at length before (see Chap.4) the guided-discovery approach in M.I.S.P inhibits hypothesising in a similar way.

Directing pupils' attention to the relevant aspects of phenomena, and guiding them towards acceptable models of explanation is clearly a necessary part of science teaching. Nor is there reason to criticize the teacher, who is carrying this out very skilfully. The question to be asked is whether the whole of pupils' verbal or written participation in science lessons should be confined to putting words into slots, or rather to attempting to intuit the teacher's intentions. This would be to ignore the pupils' power of constructing meanings, and to fail to give them active experience of scientific thinking: finding questions, formulating hypotheses, criticizing, using evidence, and so on. The purpose here is to ask whether part of children's introduction to science should not be the experience of taking responsibility for thinking, and this implies that they should be required to 'think aloud' in exploratory talk and exploratory writing.

Here is some writing which is clearly not exploratory. (The spelling has been corrected).

Object : Titration

Method : We filled a pipette to the 25 cc mark with an alkali and put it into a beaker. We filled a bubrette from 0 cc to 50 cc with an acid. We added a few drops of universal indicator (Teacher's correction: methyl orange) to the alkali. We added drop by drop the acid until the colour turned green (Teacher's correction: orange). Then do the experiment again and evaporate until we get a solid.

Result : It needed 14 cc of acid to turn the indicator green which is neutral. We did the experiment without the indicator and added 14 cc of acid. The solid left after evaporation was salt.

One might ask what value there was for a thirteen-year-old in writing this after a lesson. The emphasis falls not upon understanding but upon a cookbook procedure. There is hardly a sign of scientific thinking in this piece of writing: it appears to be a verbal routine carried out solely to fulfil homework requirements, and addressed to the Teacher as Examiner, that is it was "writing which the child appears to be producing simply to satisfy a teacher's demand, and on which he expects to be judged or assessed". Such writing is a display of competence external to the writer's concerns, and thus neither a reflective attempt to understand nor an exchange of ideas with the teacher.

"Through the Eye of the Pupil", a collection of children's writings about science selected by the Science Teacher Education Project (S.T.E.P), well illustrates that writing can be an instrument of thinking even for young and less able children. The children in their writing clarify that they know, ask questions, formulate hypotheses, plan or describe practical tests, interpret observations, and search for general principles which can integrate and explain what they already know. Clearly all this writing arises from skilful teaching, since it must have been teachers who helped these pupils to focus their attention on a topic, and yet at the same time were able to persuade them to take on the responsibility for their own thinking. For a teacher (and curriculum maker) to exercise his authority in ways which increase pupils' participation is no abdication of responsibility: indeed it requires considerable planning and self discipline.

Therefore, for the pupils to experience science in action (like Freire's praxis (1972) involving a notion of 'dialogic education' in which teacher and student engage together in a critical approach to 'reality'), hypothesising through talking and writing must be given free rein. The pupils must be allowed to think and discuss the various aspects of a problem; in so doing they exercise their mind in looking at the different facets of the problem and train themselves at decision-making. It is not so much relevant, at this stage and in this context, that a decision be right or wrong. What is more important and urgent is that the citizens of tomorrow learn how to take decisions after weighing up the pros and the cons. This kind of education is Education for tomorrow. It has survival value. Such an education is essential if we are to survive in a fast changing, technical and scientific age. We need a citizenry which is adaptable and can easily adjust to changing conditions. Such an adaptation is fostered by an ability to think critically which itself can be engendered by science education. For an overpopulated small island like Mauritius with its almost total dependence on a single cash crop and its lack of mineral resources (see Introduction), there is no doubt that an appropriate science education will be of immense value.

As Young and Whitty (1977 : 35 - 37) say:

> "The recognition that there is no one 'reality' will enable pupils to develop a 'permanently critical approach to "reality"........

> " .... knowledge is seen as inextricably linked to methods of coming to know and any supposed dichotomy between them is therefore false".
>
> (Young and Whitty 1977)

Once again, it is shown that hypothesising must supersede knowledge in importance in the context of the school science education. The guided discovery approach is too restrictive and must be modified into a course with great flexibility in which observations and hypothesising play a leading role.

## 5.2 A REDUCED EMPHASIS ON KNOWLEDGE ACQUISITION

Despite what the "Aims and Objectives" of M.I.S.P purport to say, an analysis of the texts of M.I.S.P or a look at the Integrated Science Teaching Syllabus (Appendix B) will show that the knowledge content amounts to a great deal. For example, in Matter and its Reactions (Form III Chemistry), the occurrence and/or preparation, the properties and uses of metals, non-metals, gases, acids, alkalis and some compounds are listed. In Matter and Energy (form III Physics), the concepts and definitions of force, work, power, energy, temperature, heat, heating effects, heat transfer, magnetism, electricity - static and dynamic, light and sound, are all to be treated in breadth, if not sometimes in depth. In Matter and Life (Form III Biology), investigating living things, nutrition, ecological studies, transport, breathing and energy production and reproduction are to be studied.

As outlined previously (p.25), the Form III Science course is a concession to specialist science teachers who already want as from Form III a preparation for School Certificate (Form V) Examinations in science subjects. This might have been a workable solution in principle but for the fact that at Form III, the National Examinations constitute a terminal course for school-leavers (see p.7). Teachers, pupils and their parents might wish to use the Form I work as a foundation course for Form III. No one can blame them for such a scramble. Consequently, the emphasis on knowledge acquisition moves down the line in spite of teaching strategies supposedly to the contrary. The main stumbling block is that teachers teach to a syllabus and, more often than not, for examination purposes. So any changes bearing on the reduction of the knowledge emphasis have to centre on the syllabus and the overarching examinations. It is understood that an appropriate teaching approach is used to bolster such a scheme, that is, a scientific method is adopted whereby observations, hypothesising and experimentation predominate.

By syllabus is meant also the accompanying M.I.S.P texts. Now science texts, considered as formal vehicles of transmission of an image of science, find Kuhn (1970) reminding us that "a concept of science drawn from them is no more likely to fit the enterprise that produced them than an image of a national culture drawn from a tourist brochure or a language text". By this, Kuhn means that much of science education, as practised in the classroom, is currently unscientific: science is regarded only as a body of knowledge and teaching has but one purpose which is to transmit information. This sounds like a bold statement, perhaps overstated, yet it is close to home. For example, Young (1974: 51-60) says:

> "Historians of Science, and, as Kuhn discusses, textbook writers, provide through their cumulative conception of science a view of science at a particular time as an achieved product or body of knowledge.
>
> Prevailing notions of science education present it as an almost paradigm case of passive socialisation. Not only nature, but learner-scientist, Kuhn (1970) argues, get forced through the conceptual boxes of the dominant scientific theories of the time. Criteria of adequate science, drawn like notions of 'structure' from the specialised activity of the few, are used

> to construct courses and examinations for the <u>many</u>, most of whom become failures or reject it themselves. The activities of science teachers are as reproducers of the knowledge produced by others rather than engaging in inquiry with their pupils".

School science, the pedagogically induced image of science, is a sort of 'mythical' or cold science. School science perpetuates an image of scientific activity and scientists which has little in common with the activity in which scientists engage in the laboratory.

As Sund and Trowbridge (1967) characteristically remark:

> "Unfortunately, a student can learn science as a body of knowledge without understanding it as a process and without knowing what enquiry involves. The recorded knowledge of science is history produced by men using scientific processes. Teachers have traditionally emphasized this product of science but have failed to give students an understanding of the means of solving problems, one of the most valuable educative objectives for science instruction".
>
> (Sund and Trowbridge 1967)

It is quite clear that shcool science concentrates on the knowledge component rather than on the enquiry component. There are two reasons for this. The first one is to initiate the learner-scientists into normal science by forcing them through the conceptual boxes of the dominant scientific theories of the time (Kuhn 1970). The second one is to educate the members of technological societies in the use of technology in the home and at work. These two reasons are quite untenable.

Let us condiser the first reason. It is important to emphasise that teachers of science, like all teachers, cannot concentrate their attention on the potential entrants to the profession of scientist. Bullock (1976) sees this as only half the job:

> "..... the tougher but equally important part is the education in science of the much greater number who are not going to become scientists and have no special aptitude for scientific studies....."
>
> (Bullock 1976)

Bondi (1975) quantified the problem in a neat calculation which estimates the proportion of our pupils destined for academic science as less than one percent:

> ".... it is surely not right that we should model

> the education of 99 percecent to any extent by the needs of the 1 per cent. We must not forget that 1 per cent, but we must not be dominated by its needs".
>
> (Bondi 1975)

Layton (1973) is less exact about the proportion but argues that the educational requirement is two-fold:

> ".... to produce scientists and a laity with sufficient understanding of science and its influence to participate in fruitful debate".
>
> (Layton 1973)

These quotations indicate that school science could contain less factual knowledge. Yet the current trend in science seems to be to push highly sophisticated principles and techniques further and further down the educational levels. For instance the transistor which was once taught at University level is now being taught to Form V pupils as part of their science course. Indeed it seems that to attempt to inculcate complex principles to younger and younger students is an educational virtue, to be looked upon with favour in current education.

De Beer (1969) attacks this notion on the grounds of biological principles. Firstly, he emphasises that this educational strategy engenders educational precociousness among students. These students lack an appreciation of a wide variety of subject areas. He contrasts this educational strategy with biological principle important to human beings - 'delayed development'. Secondly, he implies the biological principle of the 'critical periods' hypothesis (Scott 1962; Bowlby 1971). (It seems that children are more sensitive to learning certain concepts and language at one stage and not at other stages of development)..Furthermore, if a child misses a critical period, it will be to his detriment:

> "The second great mistake was to go on the principle that as more and more is discovered, more and more must be taught. This inevitably leads to a premium on precociousness, for as economic reasons limit the time during which a student can be kept at university, time is borrowed, or rather mortgaged, at the other, earlier end of curriculum, and specialisation is pressed back into the schools. Advanced subjects are introduced prematurely at the expense of more general subjects, and worse still, the competitive nature of examinations for scholarship confers an advantage on the precocious which is the exact

opposite of one of the most important processes responsible for the evolution of men: delayed development ....
Besides this, subjects introduced prematurely are only imperfectly appreciated, and at the expense of more basic subjects which are increasingly difficult to acquire at later ages. Mathematics and modern languages do not come so easily to students after they have spent so much precious young time with test-tubes and dissecting dishes".

(De Beer 1969)

It would seem that if educators appealed to biological theory they may have a great deal to contribute to many areas in education:

"With the progress of science during the last half-century, the situation has really become easier to cope with, without anyone's noticing it, not in spite of the progress, but because of it. Sir Peter Medawar has reminded us that whereas in the early decades of this century, the different branches of science were in chaos, the discoveries that have since been made throw light on general principles of increasing breadth which require for their teaching a few well selected examples, leaving the whole mess of unwieldy detail growing like a snowball to be acquired later, and to fall into place if necessary. In biology at any rate it is all so much more tidy that there is no justification for the precocity scramble ......

The situation has also become easier because of the increasing realisation of a great truth of which sight should never have been lost; the mental processes involved in observation, verification, and use of imagination in producing ideas are fundamentally the same in poets, essayists, artists, musicians, and scientists. This is why the notion of 'Two Cultures' is exaggerated".

(De Beer 1969)

The second reason concerning technology is open to argument. It is probably true that not one of us can avoid using the products of advanced technology even should we wish to do so. But is there a pressing need for the user of a particular machine, be it television, a motor car or detergent, to understand either its particular mechanism or the general principles on which its operation is based? Most of us can continue to walk safely and comfortably in ignorance of the chemistry, biology and physics that went into the design and manufacture of any particular synthetic soled shoe.

Ignorance in any form is seldom desirable, but the point at issue is that it is not always inhibiting. Being unaware of, or failing to understand the concepts which underpin our technology does not prevent adequate, competent or even skilful use of that technology. For as long as science is not necessarily an unceasing joy for those who are made to study it, nor obviously relevant to their future careers we will need good reasons to insist on teaching it to them. However, it is an advantage, and at times it is very important, to know the practical relevance of science to everyday life. For example knowing the principle that evaporation removes heat can help someone to realise that he can easily catch a chill if he stands in the wind with his wet body after a swim. He must dry himself very quickly. (see M.I.S.P Book I pp. 59-60). Coming back to the first reason concerning the 'knowledge explosion' and its imposition at the school level, there is no doubt that a lot of pruning has to be done on school science texts. Maybe a 'drift' from science through the boredom of learning masses of unconnected 'facts' would be averted! For example, in M.I.S.P Book I THEME 3, the temptation is great for the pupils to learn, by rote or otherwise, the action of air in different situations as well as the properties and composition of air. Yet the idea is to carry out practical work with air and different substances.

Another example comes from M.I.S.P Book II THEME 7 Page 18 where the various kinds of fish in Mauritius are categorised for comparative study. The danger exists that pupils may try to commit them to memory. Or in Matter and Life (Form III Biology), the structure of the alimentary canal on page 33 and that of the heart on page 72, or page 86 with the diagram of the breathing system of man, all their labelling may be learnt.

It is not that facts are not useful but they must not be allowed to clutter the pupils' minds. Bondi and Clark (1977) see the need to redefine the aims of compulsory, formal education, and do so as follows:

> "Education has to be supremely useful to a child in at least three directions, It must help him to contribute to society by earning a living, to understand the forces - especially the persuasive forces -that shape the society in which he lives and in which he is called upon as a responsible citizen to make decisions, and to enjoy more fully the experiences society can offer".
>
> (Bondi and Clark 1977)

Throughout, the knowledge component in science education is downplayed for the benefit of hypothesising. M.I.S.P has to be viewed in the terms: greater emphasis on observations and hypothesising at the expense of facts, principles and concepts masquerading as facts. Esoteric knowledge must not have a large role to play in science education. A radical change is needed in M.I.S.P to bring the stated objectives closer to reality. What about experimentation? A closer look at experimentation is also advisable in order to separate the chaff from the wheat.

## 5.3 A REDUCED EMPHASIS ON EXPERIMENTATION

Although experimentation is an important component of the scientific method, its misuse can be as deadening as the emphasis on scientific knowledge. Very often, laboratory exercises belabour the obvious, wasting a great deal of valuable teacher and student time.

> "Yet science courses at all academic levels are traditionally organised so that students waste many valuable hours in the laboratory collecting and manipulating empirical data, which, at very best help them rediscover or exemplify principles that the instructor could present verbally and demonstrate visually in the matter of minutes. Hence, although laboratory work can easily be justified on the grounds of giving students some appreciation of the spirit and methods of scientific inquiry, and of promoting problem solving analytics, and generalising ability, it is a very time consuming and inefficient practice for routine purposes of teaching subject

matter, of illustrating principles, where didactic exposition or simple demonstration are perfectly adequate".

(Ausubel 1965)

Moreover it may hinder students in their appreciation and interest in science:

"The unsophisticated scientific mind is only confused by the natural complexities of raw unsystematized empirical data, and learns much more from schematic models and diagrams; and following laboratory manuals in cook-book fashion, without adequate knowledge of the relevant methodological and substantive principles involved, confers about as much genuine appreciation of scientific method, as putting on a white 'lab' coat and doing a T.V. commercial for "Roll-Aids".".

(Ausubel 1961)

Laboratory work may become deadening and formal. Yet it has been introduced into courses apparently to reduce 'rote memorisation'. The type of laboratory investigation presented in science is likely to favour the very process they seek to prevent:

> "Problem solving can be just as deadening, just as formalistic, just as mechanical, just as passive, and just as rote as the worst form of verbal exposition".
>
> (Ausubel 1961)

Furthermore, the shortage of apparatus in most Mauritian schools as reported by Chung (1977: 28) prohibits an extensive array of experimentation. This restriction is in live with the advocated equality of educational opportunity (see p.10) unless one wants to favour the elitist schools. For the latter category of schools however, supplementary learning material is available so that those pupils of greater educational potential are not held back.

It is psychologically defeating for teachers and pupils to open their texts of M.I.S.P Form I for their first practical work at page 1 and to realise that they cannot do the experiment. Most schools do not have a Bunsen burner. This handicap is extended to the next two activities on Guessing Hotness and Measuring Hotness in which the burner is supposedly needed for heating purposes.

Surely it would have been more to the point to use a lighted candle (see Act.1.4 in M.I.S.P. Book I) for the first practical work. The pupils could have done Observations and Hypothesising with it : investigation on Solid, Liquid and Gas states of the candle, physical and chemical changes, its flame without a continuous input of air. This experiment would be familiar to the pupils but this time they would be studying it in a systematic or organised fashion.

THEME 3 work requires magnesium, sulphur, Bunsen burner, tripod, gas jar, trough, conical flask and some other pieces of apparatus. Many of these are not available and so a lot of pupils are penalised. But many an enterprising teacher gets round the problem by tackling these activities through didactic exposition. So the pupils are happy; they get the 'facts' from the teacher and proceed to learn them by rote. Where does science come into it? Scientific knowledge is given and reified; the process is non-existent.

Tin-foil, less striking than magnesium on burning, could have been used and its burning compared with the non-burning aluminium metal in the form of pots and pans. As various chemicals are not available in many schools, it is not advisable to give practical work on them unless alternatives are suggested and their availability made certain or a scheme is devised whereby equipment and apparatus are made available to schools on loan or on a donation basis.

Visual aids in the form of charts and drawings pertaining to the activities in the texts or beyond need to be available for use. There is one field of interest of extreme importance to M.I.S.P which is coming into the picture. It is the concept of locally made science apparatus commonly called low cost science apparatus making. This scheme is undergoing development at the M.I.E.

Such a scheme has many advantages. Firstly the lack of apparatus in schools has an adverse effect on the teaching of science. How can pupils study science through observations, hypothesising and experimentation if there is not the simplest equipment around? Teachers will be forced willy-nilly to fall back on didactic exposition. Evidence from many countries has shown that lack of suitable apparatus is the main cause of the pupils' failure to achieve the important objectives of a modern science course.

Secondly, the development of local low-cost apparatus enables a great saving in foreign currency exchange to be achieved. A great deal of relevant apparatus can be made locally, and by the teachers themselves, at a cost many times less than the cost of imported materials.

Thirdly the apparatus would be more relevant and effective. The ability to improvise is an essential part of any modern science course, and teachers and students must be trained to develop this ability. It is important that a science course which aims to develop initiative, imagination and adaptability in pupils, must assume similar qualities in the teachers.

Fourthly, the essense of development of low cost apparatus is that the materials chosen are cheap and easily available. The major item in the making of apparatus is wood. Ideally the wood used should be easily available to teachers in schools who, when trained, wish to prepare further items for their class. Therefore the obvious choice is wood from packing cases and crates, for this is readily available and very cheap.considering the quantity of wood obtained in this way. Also the wood, though rough, is ideally suited to the scheme for it is very easy to work, does not require a preparation workshop and does not split when used with nails. Use of crate wood also emphasises the importance of using scrap materials and thus saving money for glassware and other equipment that cannot be made. By making apparatus out of wood and metal, most items are very strong and can be treated very roughly without damage. On the other hand, much of lower school manufactured equipment is made of plastic which is easily broken and difficult to mend.

Students use low cost apparatus more readily. There seems to be little doubt that an expensive piece of apparatus has a strongly inhibiting effect on a young student. Faced with an expensive apparatus, the inexperienced student will either not risk using it at all or will do precisely what the teacher says, and no more. But a low cost apparatus can be knocked over without harm. The student is far more willing to have a go and try out his own ideas. The low cost apparatus can be made to illustrate a precise principle. For example, a balance bar (see M.I.S.P Book I p.88) made locally is used to introduce the concept of the Moment of a Force. It is designed with only three holes each side. This keeps calculations extremely simple. In addition the beam will either stay level or fall right down one side if the laws of moments are broken. This results in the bar being very easy to use so that even young children can have fun with the experiments and master the concepts at the same time.

Again, in electricity, a switch is a simple circuit breaker, but in a real switch this fact is apt to be hidden (see M.I.S.P Book II p.73). The mechanism is often complex, and the works hidden in plastic so that the student cannot see clearly how it works. The switch made for the Integrated Science Project is cheap and simple; it shows quite clearly the function of making and breaking a circuit. In fact when properly designed, home made apparatus can be superior to bought materials for teaching basic principles and have direct relevance. At the moment, the

M.I.E Science Department is making prototypes of apparatus needed for M.I.S.P and is training teachers in the making and use of them. The next phase might be large scale production to supply schools with low-cost apparatus.

## 5.4 CHANGES IN THE STRUCTURE AND CONTENTS OF M.I.S.P.

From the arguments on the 'knowledge explosion', the overloading of teaching syllabuses and the assumed precociousness of pupils, it is necessary to have changes in both the structure and the contents of M.I.S.P.

### 5.4 (a) STRUCTURAL CHANGES

At present there are 3 texts being used for Form III Science. These are Matter and Life, Matter and its Reactions, and Matter and Energy; they use assumed names when, in fact, they represent Biology, Chemistry and Physics. As outlined before, they are a concession to specialist science teachers who want a more academic bias to prepare the ground for later single science discipline studies. But, as Bondi and Layton argued, this academic bent attracts only a small proportion of the school population in terms of future relevant careers. Thus this academic emphasis on the three basic sciences is untenable despite the fact that, beyond Form III , the pupils will have to receive a scientific training in what Kuhn (1970) calls the normal science paradigm. However, it may be argued that pupils who have overcome the Form III Examinations in 5 core subjects and 1 elective subject (out of Home Economics, Commerce, Art and Craft, Agricultural Education, Technical Education, Aesthetic Education and Oriental Languages) are intellectually capable of learning the specifics in normal science as from Form IV. Why cram the young minds with masses of detail when the majority of them are not going to participate, one day, in the shared possessions of the normal science community (Kuhn 1970)? It follows that the 3 texts can be combined into one single text with a reduction in content. The latter case will be discussed in the section on CHANGES in the M.I.S.P. CONTENTS.

Another important point concerning the grouping of the 3 texts into a single text is based on time-tabling difficulties. Most schools allocate an average of 5 periods per week per core subject and 3 periods per week per elective subject. As pupils are allowed to take a minimum of SIX subjects (5 core + 1 elective) and a maximum of EIGHT subjects (5 core + 3 electives), schools have to make an allowance of 8 subject fields of study (the C.J.S.E Regulations booklet refers). This being so, the core subjects need 25 periods per week while the elective subjects require 9 periods per week giving a total of 34 periods out of a school week of 40 periods. This leaves 6 periods for physical education, library study, religious or cultural activities and free periods, if any. Some schools work on a 35-period weekly time-table. Now with 3 components (Biology, Chemistry, Physics) for the Form III Science course and 5 periods per week available. for the science teacher(s) to share, those teachers who get 6 periods per week are indeed fortunate. Most of the teachers clamour for 9 periods per week, i.e. 3 per science component per week. This seems to be a reasonable request in the present state of affairs (see Teaching Syllabus in Appendix B).

A reduction in content material and the use of a single science text in Form III means that a single teacher will have to deal with the work. At the moment, 3 specialist teachers teach the 3 science components in many cases. To provide a general broad-based education, the single teacher is in a better position than his specialist colleague. More of this discussion will be aired in the section on teacher training. It is to be emphasised that we are more concerned with providing education (see Project Document p.8) than training in the Kuhnian sense.

The Form III Examinations (C.J.S.E Exams) in Integrated Science consist of 2 papers (see Appendix C).

Paper I (1 hour) has 40 multiple-choice questions based on work done in Form I, Form II and Form III.

Paper II (1½ hours) has 12 structured questions based on work done in Form III only (4 questions for each of the 3 science components). The objectives to be tested are (supposedly) not only the acquiring of a knowledge of Science (i.e recall) but also comprehension, application, skills, positive attitude and interest in Science.

There is a wide gap between stated objectives and the testing of these objectives in examinations. For example, Chung (1977) in his analysis of the Form I (1976) Evaluation Test wrote on the Behaviour-Test content Grid as follows:

> "From the analysis of the Test Paper in terms of the broad objectives of the Form I syllabus, it is obvious that the majority of items in the test were meant to assess knowledge and understanding. Fewer items were meant to test skills - of the "process" type (in constrast to the "manual" skills) - and none was set on attitudes as such".

Appendix E gives the analysis in tabular form while the Question-Paper is in Appendix D.

Unless great care is taken, examination papers will otherwise provide sanction for the over-emphasis on the acquisition of scientific knowledge with recall masquerading as understanding and application.

One way to attenuate the problem is to base the C.J.S.E Examinations on Integrated Science on the work of Form III science only, leaving M.I.S.P Form I and Form II examination free from the official point of view. In any case, it is only Paper I which tests the work done on the 3 years of M.I.S.P. On a pro-rata basis, the work in the first two years should cover two-thirds of the questions in terms of years of contact whereas it would cover two-fifths of the questions in terms of texts used. Moreover, expecting pupils to answer questions at the end of the third year on three years work definitely forces them to fall back on rote memorization unless a spiral curriculum is used. A spiral curriculum involves the same topics being treated at a greater depth as the years go by. All in all, leaving M.I.S.P Form I and Form II examination free would be more educationally sound. The explicit removal of the emphasis on knowledge acquisition would make the study of science more interesting and educationally valuable.

5.4 (b) CHANGES IN THE CONTENTS OF M.I.S.P

Until the Primary Science Curriculum becomes a reality, it can be assumed that pupils in Mauritius start their secondary education without any formal science education. What kind of science should they be confronted with? Surely, the learning of definitions of scientific terms, laws, principles, concepts and so on should be avoided. What is needed is an introductory course which interests the pupils and arouses their curiosity. This can best be done by activities involving largely observations.

Scientific interests seem to develop at a very early age (Butcher 1968). And many scientific interests begin with biology. Very young children seem to have a natural curiosity for living things (Comstock 1911; Leach 1946; Beggs 1954). Children are favourably disposed to nature-study even at primary school age.
Beggs (1954) advises teachers to:

> "Concentrate attention on living things which are real to the child, rather than upon generalities which are remote from his world of thought. One live sparrow will hold his attention better than any discussion on bills and legs of birds".
>
> (Beggs 1954)

This teaching approach provides the 'raw sense experience' to pupils in a formal situation. Thus M.I.S.P Form I can start by introducing observational studies after the style of Nature Study. This approach is presented in a readily available form (see Bailey 1903; Beggs 1954; Comstock 1960). Nature Study emphasises observation in natural surroundings, and it capitalises upon the keen interest of children. Also ob servations, as explained before (see p.64) are theory-laden. The incorporation of Nature Study (as with the incorporation of theory) would be inexpensive. Equipment for observing organisms in the field, and for keeping them in 'internal habitats' in the laboratory, costs considerably less than some sophisticated experimental equipment currently being purchased. Beggs (1954) continued thus:

> "With my subject, of course, your first concern as a teacher is to make it live for the child, so that when you come to teach nature study which deals with living things a child can touch, watch grow, and look after, your work has already begun for you. Because plants and animals change and move, children are immediately interested in them. But to keep the child's interest alive you should be more concerned with habits and adaptations of living creatures than about their external forms and outlines. A primrose far from being merely an example of botanical form, is a forerunner of spring, a thing to be looked after, with petals that attract bees and effective devices to use them for cross pollination.
>
> (Beggs 1954)

In this way, pupils would be made aware of their surroundings and more so than if they were doing laboratory experimentation.

Thus, Beggs (1954) emphasises 'observation' and 'theory'. He is quite explicit about the sustained interest which can be generated through theory, field observation and live organisms. The rationale and methods of Nature Study are outlined in Bailey (1907), Beggs (1954) and Comstock (1911). All authors stress field study, 'creative observation' (as outlined by Tinbergen) and biological theory (adaptation, 'survival value' and natural selection).

In fact, these methods are already being used through the emphasis which is currently being placed upon ecology. One is reminded of Louis Agassis' famous aphorism: "Study nature, not books" (quoted in Allee et al. 1949).

In Tinbergen's opinion, observation is an important and necessary preliminary to experiment. He said:

> "I believe that we should observe and describe before we experiment; and second, with regard to behaviour (as with all life processes) we should ask the question "What's the use of what the animal does?" Does it contribute to the animal's success, and if so, how as well as the question "what makes it happen?".
>
> (Tinbergen 1972)

If individuals have been previously educated in the problems of how local common organisms overcome the viccissitudes of their particular habitats, through Nature Study or Natural History, these people are more likely to be sensitive to the principles of conservation. Consequently, if Natural History methods were incorporated into M.I.S.P, more students would study it seriously. The sheer increase in numbers of environmentally aware individuals would serve perhaps to assure the survival of Mankind. Thus Environmental Studies have an important role in M.I.S.P. The Environmental Studies already in M.I;S.P must be modified to devote more time and space to Observations and Hypothesising (pupils' own talking and writing with the teacher managing the activities more like an adviser than like a purveyor of knowledge). Simple classification work and collection of items of interest can feature in M.I.S.P Form I.

M.I.S.P Form II may include simple treatment of solids, liquids and gases (the lighted candle experiment is a typical example), of air, water, fire (heat and light), force, energy, nutrition, blood transport, breathing, reproduction all made relevant to daily life rather than being given a detailed academic slant. Awareness of the importance of agriculture (pupils' planting of seeds and cuttings), health and sanitation is to be inculcated early in the pupils.

M.I.S.P Form III (whose pupil's work is to be examined at the end of that year) should still include observations (on animate and non-animate objects) and hypothesising on topics from the 3 basic sciences and beyond. No detailed functional mechanisms or descriptions need be learnt. The emphasis on recall is still to be minimised. Learning how to do science is preferred to learning the past achievements of science.

# CHAPTER 6

## STRATEGIES FOR THE SUCCESSFUL IMPLEMENTATION OF M.I.S.P.

Finally, we come to the most important phase of the curriculum development of any educational project. It concerns the pedagogy. Unfortunately it is not possible, due to some unavoidable constraints, to make an in-depth study of the problem, However, a brief outline will be given to light the road ahead for the successful implementation of M.I.S.P.

### 6.1 IMPLEMENTATION

M.I.S.P, being an officially-sponsored science course backed by a proposed National Examination, is nationally disseminated. The learning materials are used in all schools in Mauritius but are they used in the spirit in which the curriculum developers intended? The curriculum maker has seen its task as 'changing a system' and recognised that curriculum development in their terms is a long process with many constraints. (Stenhouse 1980:170) Are the disseminators making a breakthrough as a result of a well-taken pass or are they off-side? The project is still too young for an accurate evaluation to be made.

But from the feedback from teachers at in-services courses, from school visits by M.I.E staff and by P.S.S.A inspectors, from the one or two evaluation tests in pilot schools, one thing stands out. The lack of laboratory facilities compels many teachers to fall back on didactic exposition and consequently the emphasis still remains with the acquisition of scientific knowledge. With the help of the low-cost science apparatus making and eventually its large-scale production (actually small by world standards!) and its diffusion in schools, the activity-based approach will be taken more seriously and will find a permanent niche in schools. Another constraint on the pupil-centred approach will be removed if M.I.S.P Form I and Form II are made examination-free in the official sense, as argued before.

The two main constraints remaining centre on teachers and examinations.

## 6.2 TEACHER TRAINING

Teachers are the indispensable agents of change. How can we get teachers to teach integrated science? This question has been raised at the Maryland Conference on Teacher Education for Integrated Science (Richmond 1974). The focal point of concern was the science teacher. The consensus arrived at was that preparing teachers to teach integrated science meant outfitting them with a proper array of knowledge, skills and attitudes. In addition, it should be said that they need a deep immersion in the philosophy of science to understand the processes of science. They should realise the dichotomy between the process and product of science. This will open their eyes on the importance of hypothesising in the educational context. There is no doubt that the successful implementation of integrated science courses must wait on a complete reorganisation of the teacher education system.

However, in the short term, in-service and pre-service courses have to be held regularly. Not only training in teaching techniques is to be provided but training in the improvisation of science apparatus is just as important. Teacher trainees should learn how to do science rather than just acquiring scientific knowledge. Teachers' guides are necessary tools for them. Furthermore regular school visits by M.I.E staff as well as by P.S.S.A inspectors to provide advice and support to teachers must not be overlooked. The identification of enthusiastic teachers will help to pick out those who can act as "Masters" in their schools to promote the implementation of M.I.S.P. These "Masters" can also act as leaders in Teacher Centres to support their colleagues on a regional basis.

It is regrettably true that most teachers teach as they themselves were taught. The teacher in general is often not only conservative in his nature, but is under strong social pressure to remain so; moreover he has had little in the way of social training. He sees his role as that of teaching science and is concerned with what he was trained to think of as important: covering the syllabus and getting pupils through examinations.

But science education must be seen as an agent of social change. Its aims and outcomes must be described and defined in social terms and the curriculum work associated with it must be a continuing social evaluation. However no one placed much stress on the idea that the teacher is engaged in changing society. Such an idea is too remote because his task and his training have been set in the dimensions of immediacy. Thus there is need to give to science teachers an understanding of their social functions which will result in their using their knowledge of science to achieve social change. The task is not easy; What is to be sought is not merely an understanding of social functions, but the acceptance of a new role as an agent of change. We need teachers who will produce innovators, who will produce critics, who will stir interest, challenge effort and instil in the minds of youth that divine discontent which sets off the search for the new and the better. If a developing country like Mauritius is to have the necessary people with enquiring minds (see Project Document p.8), the necessary technicians and craftsmen with a sense of self-reliance one of the highest priorities mustbbe the training of teachers or even the re-training of teachers.

Meanwhile, M.I.S.P is here and teachers find themselves in a dither. As Goldsmith (1973) put it:

> "Science teachers around the world are in a whirl. They are aware that their walls are falling down, and that their teaching is being exposed as self centred and inadequate. But where are the new boundaries to be constructed. And what is to be the new teaching? ....
>
> We know that the conformist is always safe. Life is laid out for him and responsibility is nil. But that is not what the next step in science teaching is about.
>
> Integrated science should plunge into the unknown, with the teacher preparing charts as he goes along".
>
> (Goldsmith 1973)

This bit of advice is expanded by Knox (1969) into a scientific method for the teacher to use in his teaching:

"You will often find a fairly precise pattern of investigation will give the most rewarding results. Initially you should try to identify the problem you are going to investigate. It often pays to write it out as a statement. You should then search the available literature to help build your background information - it is here we hope the textbook will be of assistance. This knowledge, together with your own observations of the organism or situation, should then be surveyed to see what information can be discarded as being irrelevant to the problem and what patterns or generalisations are apparent. Using your background of knowledge and understanding of biology in general you should now seek to explain why such a pattern or relationship might exist or appear to exist - in other words you are developing an idea, theory or hypothesis. You or yourclass may even have several different ideas. Your next move is to suggest ways of testing your ideas. What experiments could you design to test your theory? Your responses to successes and failures will be a measure of your ability to overcome obstacles, and at the same time, you will know the excitement of adventuring after truth. You will come to realise with humility, that ideas can stand only as long as they remain consistent with the observed facts".

(Knox 1969)

This quotation advises teachers to use the scientific method along the same lines as that advotated in this thesis. Thus observations and hypothesising can take their rightful places in science education. Teaching will be the richer for it.

The new concepts and methodology adopted in the new curriculum put new demands on the teachers who are not prepared for the change. In order to meet such challenges and demands, corresponding changes and improvements should also be made in the curriculum and methodology of training at the MIE for both pre-service and in-service courses.

There is always a gap between the intended and the actual outcomes of a developmental or training programme. There is need for continuous reinforcement of what is learnt by teachers in theory and what is practised in classroom situations. This can be done by developing conceptual literature, illustrative materials and specimen material for guidance of teachers.

Public examinations (CJSE) set not only the expected performance standard of pupils that even engender impact on teaching-learning practices in the classroom. Therefore, it is essential that validity and reliability of these external examinations must be ensured to have positive impact on teaching-learning process. Like any other innovation, success of any project of curriculum evaluation would depend on the teachers who are not only the agents of change but also the practitioners of change. It is, therefore, obvious that for proper implementation of the new curricula vis-a-vis evaluation of curricula, the involvement of teachers be considered a necessity. For effective participation in the evaluation process of textual material, there is need for intensive training of teachers in the efficient use of textbooks, appraisal of texts, preparation of objective-based instructional material and development of objective-based test material for judging student's learning and the curriculum.

The role of the Head of the school is not to be minimized: he represents the authority which, in principle, supervises the teaching strategies being used inside and outside the classroom. He, too, is an important factor in the implementation process.

## 6.3 EXAMINATIONS

One of the most potent seed-beds for a 'modernised' curriculum in the local scene lies in the interplay between the examinations and the schools and the teachers in them. The examinations will provide the ultimate lever that will help push the curriculum through when everything else seems to have failed. The impact of Public examinations (CJSE) on the teaching-learning practices in the classroom has already been mentioned (see 6.2). That is, the teacher is bent on covering the syllabus and getting pupils through examinations. Fair enough! It is the teacher's duty to teach the pupils and, to show that he has done it well, he relies on the examinations to prove his competency.

This being so, examinations consequently direct the teaching emphasis within the classroom: By using this feedback loop, curriculum developers can force teachers to teach M.I.S.P along the lines of the scientific method already explained provided that the examinations test these components of the scientific method. Teaching and examining are hence interdependent.

As M.I.S.P emphasises observation, hypothesising, experimentation and inference, can examinations test observations and hypothesising (they are subjective!)? Although, observations are theory-laden and hypothesising gives rise to various answers depending on the lens used, correct marking can be done provided the examiners have ability as examiners. As Stenhouse (1969) says:

> "Where several thousand examinees have to be graded, for example, a well-constructed objective test as a component in the measuring instrument can function as a device for standardization among the examiners. The existence of an 'objective' mark merely as a standard

of comparison, as a 'norm' in the descriptive but not the prescriptive sense, can serve very usefully as a yardstick against which those examiners who are at variance with the majority will stand out. Because they stand out, their standards and techniques can be scrutinized; and depending on the perspicacity and imagination of the persons who control the examination, some of the "discrepant" group may be dropped from the panel or instructed to amend their procedures, while others may be selected as models upon whose superior judgement improvements in overall standard and techniques may be built. There is nothing whatever to be gained by the bland assumption that all examiners are of equal worth, that all do the same sort of job in the same sort of way - but to rush to the opposite extreme to assert that "since there are disagreements it is impossible to know whom to trust", is equally fatuous. Examiners must be appointed on the basis of their ability to examine relative to a particular end or purpose. In order that those who appoint them may have some grounds for making the appointment, it is necessary that examiners should have given evidence of their ability as examiners. The only way in which this can be done is for prospective examiners to be given a full-scale opportunity for plying their trade and showing how well they can perform. They must,, obviously, be safeguards for the examinees during the "examination of examiners"; one safeguard is a large scale standardized objective-type test as a component in the total examination. Thus such an objective-type component has a double function in relation to the individuals who are to examine by means of essay-type texts, interviews, practical tests of various sorts, or even by other objective-type tests: it simultaneously provides a safeguard for the examinees, and gives a context against which the performance of the individual examiner can be assessed .......

..... An examiner who awards high marks to "learned fools" condemns both himself and those who appointed him and/or fail to remove him. At one end of the spectrum, the people favoured by a thoroughly bad judge can safely be written off as themselves thoroughly bad; while those whom he calls "bad" may be so, but may also be very good. Thus the opposite of "good judgement" may be "bad judgement" in that values are simply inverted; but it may also be "no judgement", in that one cannot safely infer anything at all from the decision of a bad judge.

(Stenhouse 1969: 231)

Thus it is possible to mark questions on observations and hypothesising. In so doing, science teaching in lower forms can move away from the acquisition of knowledge and be itself, that is, it enables pupils to investigate like scientists. The pupils have the opportunity to learn to think critically and take decisions. Such learning outcomes form part of the scientific literacy essential for the general broad-based education of pupils who will become the responsible citizens of tomorrow. Then and only then, can we have some degree of congruence between education and the 3 major institutions basic to a human society (see p.5):

| | |
|---|---|
| EDUCATION | POLITY |
| STRATIFICATORY SYSTEM | ECONOMY |

## 6.4 CONCLUSION

The concluding remarks can be introduced by a quotation from Ramage (1967):

> "Much of the recent work on new schemes for school science education has been marred by excessive attention to means and too little to ends. Much consideration has been given to the mechanics of teaching and learning science, but far too little to philosophical whys and wherefores. For example, the disjointed list of alleged aims for one biology course makes no distinction between those aims which are scientific in general and therefore attainable through any branch of science, and those which are biological in particular and so require specifically a course in biology".
>
> (Ramage 1967)

The general aims refer presumably to the scientific method comprising observations and hypothesising in particular whereas the specific aims largely include biological knowledge. The former aims have survival value in the sense that it provides an opportunity for scientific thinking and decision-making".

> "And just as many arts graduates have found their way into science-based industry, perhaps the scientist should now assert the usefulness of his education as a training for life rather than just a training for a job in science ......
>
> ...... In the end, science is a way of looking at the world: who can say of any job that it will not benefit from being occupied by someone who looks at it from a scientific way?"
>
> ("New Scientist" Vol. 50, No. 752, May 20, 1971: 458).

'Ways of looking at the world' are implicitly theoretical. It is therefore advisable for science to retain its vocational orientation while also incorporating theory into curricula and courses. Science teaching should be such that it encourages the student to think for himself. In many parts of the world it is now accepted that encouraging a student to rely on his own reasoning powers, to help him to appreciate how to devise his own experiments to find solutions to problems which are real to him, is substantially more important than learning formal definitions or memorising pages of a textbook about Newton's laws of motion or the energy levels in a hydrogen atom.

As the President of Tanzania, Nyerere (1967), has said on repeated occasions, the need is for self-reliance. This self-reliance does not come through the rote memory of factual knowledge, but through experiencing what it is to be a scientist-for-the-day. The solution lies in changing science education so that all citizens are educated to make intelligent decisions, based on an understanding of their environment, carried along by a constant inquiring mind, and reinforced by the ability to identify and solve problems arising from the needs withing this environment. The ability to think independently and to reach conclusions only on the strength of reliable evidence will then help people to share their intellectual resources in communal planning where decisions are made. These decisions will depend on evidence presented, interpretations shared and the amount of understanding acquired. This can be contrasted as follows with science education in the past:

> "We gave them answers and kept the confidence to ourselves. We gave them memory and kept the thinking

to ourselves. We gave them marks and kept the understanding to ourselves. This science education of the past must change".

(Lewis 1979)

Curriculum Development is a dynamic process and its renewal after 3 to 5 years is necessary. In fact, they constitute a cyclic process. However, if renewal is done on the basis of experience and research findings, it is likely to be more realistic and functional. It is, therefore, desirable that research projects related to curriculum product, impact, processes, strategies and inputs may be undertaken in Integrated Science. This would not only ensure validation of curriculum products and processes but would also lead to staff development at the MIE.

* * * * * *

# APPENDIX A

List of curriculum writers:

## M.I.S.P Forms I & II

Dr Michaël ATCHIA - Biologist

Mr Peter DAVIS - Chemist

Mrs Devi DYALL - Chemist

Mr Eric NICOLAS - Chemist

Mr Michel C.H. SIN YAN TOO - Physicist

## Science Form III

1. Matter and Life

   Dr Michaël ATCHIA - Biologist

   Mr Claude MICHEL - Biologist

2. Matter and Energy

   Mr Michel C.H. SIN YAN TOO - Physicist

   Mr Daniel LI KAM WA - Physicist

3. Matter and its Reactions

   Mr Peter DAVIS - Chemist

   Mrs Devi DYALL - Chemist

   Mr Ranoo HUNMA - Chemist

   Mr Eric NICOLAS - Chemist

# INTEGRATED SCIENCE

APPENDIX B

*Subject Code No. 350*

## TEACHING SYLLABUS

The content of the teaching syllabus for Forms I and II is indicated in the CJSE Regulations and Syllabuses under Themes 1-5 (Form I) and Themes 6-16 (Form II).

For details of these Themes, please refer to MISP Form I and Form II text-books.

The detailed teaching syllabus for Form III is separated into three parts:

Matter and Life;
Matter and its Reaction;
Matter and Energy.

Throughout the course, emphasis is placed on activities carried out by the pupils themselves either individually or in groups. It is only through investigations that Science is learnt.

The CJSE Examination in Integrated Science will bear the above emphasis. In other words, the objectives to be achieved and the objectives to be tested are not only the acquiring of a knowledge of Science (i.e. recall) but also comprehension, application, skills, positive attitude and interest in Science.

### MATTER AND LIFE

*Introduction*

What is life? What does being alive mean? What would planet Earth be without living things? How do living things work? What can they do? How did they originate? How do they spread? Where are they found? How do they keep existing? How do they relate to each other and to their environment?

The above are some of the basic questions which will be raised during the course. Through activities and experiments, the student will come to find out some answers and through this come to learn more about his/her own self.

*Theme 1: Investigating Living Things*

Examples of living things. Investigating living things by listening, looking, tasting, smelling, touching and handling.

Investigating living things by counting and measuring. What can living things do?

*Theme 2: Nutrition*

Food. Test for starch, glucose, proteins. Energy from food; daily energy requirements. Common sources of carbohydrates, fats, proteins, vitamins and mineral salts *(restrict the study to vitamins A, B complex, C, D and to Calcium and Iron)*. Alimentary canal; food supply, preparation, eating and digestion.

Food production.

Composition of foodstuffs in common use in Mauritius, Réunion, Rodrigues and Seychelles. Food manufacture in plants (photosynthesis). Conditions necessary for photosynthesis (experimental study).

*Theme 3: Ecological Studies*

Animals active by day or night.

Reaction of plants and animals to light, humidity, heat. Distinction of animals and plants (study of the distribution of mosquitoes in Mauritius, of common plants in relation to altitude). Crowding and dispersal.

A medium for life (air, land, water).

Alternative studies (to be carried out over a period of at least one month):

(a) Study of animals and plants in a bamboo hedge

*OR*

(b) Study of a plot of wasteland.

*Theme 4: Transport*

Circulation and heart-beat in man. Effects of activity on heart-beat. Functions of heart and blood. Blood-vessels.

Transport in plants. Absorption of salts and transpiration.

*Theme 5: Breathing and Energy Production*

Breathing in man.

Effect of exercise on rate and depth of breathing.

Measurement of lung capacity. Lungs and how they work. Composition of inspired and expired air.

Breathing in fish: gills and gas exchange.

*Theme 6: Reproduction*

The biological and social aspects of reproduction in man. Population and sex education.

Finding out about your past.

Male reproductive system; female reproductive system; male and female secondary sexual characters. Stages in development - from release of egg through fertilisation to birth.

Reproduction in flowering plants. Life-cycle of a plant; structure of flower pollination and fertilisation. Fruits and seeds.

Structures of some common flowers of Mauritius.

MATTER AND ITS REACTIONS

*Theme 1: Some Properties of Chemicals*

Occurrence properties and uses of metals and non-metals; differences between mixtures and compounds (illustrated by those of a mixture of iron and sulphur and the compound iron sulphide); physical and chemical changes (illustrated by changes in state, the action of heat on salt hydrates and carbonates, sublimation); determination of the melting point of a solid (naphthalene), using a cooling curve; determination of the boiling points of pure and impure liquids; simple explanation of the states of matter in terms of the particle theory.

*Theme 2: Symbols, Formulae and Equations*

Definition of symbol; symbols of common elements; definition of valancy and formula; the writing of simple formulae and equations.

*Theme 3: Carbon and Carbon Monoxide*

Differences in properties of the allotropes diamond and graphite, explanation of the differences in terms of their structure, uses of diamond and graphite, other forms of carbon (making wood charcoal, coal as a fuel); carbon monoxide and its properties, carbon monoxide poisoning and the danger of burning fuels in badly-ventilated rooms.

*Theme 4: Something about Oxygen*

Preparation of oxygen, using hydrogen peroxide and manganese dioxide, burning of metals (magnesium, calcium, zinc, iron) and non-metals (carbon, sulphur) in oxygen; properties of basic (alkaline) and acidic oxides (reaction with water, litmus, acids), amphoteric oxides, neutral oxides; presence of noble gases in the atmosphere and the uses of some of these gases; air pollution (sulphur dioxide, sulphuric acid, carbon monoxide).

*Theme 5: Something about Hydrogen*

The formation of hydrogen by the action of metals (calcium, sodium, potassium, magnesium, zinc, iron) on water; the preparation of hydrogen from zinc and dilute sulphuric acid; the properties and uses of hydrogen.

*Theme 6: The Activity Series of Metals*

The burning of metals (calcium, copper, iron, lead, magnesium, zinc, sodium, aluminium) in air; the action of water on the above metals; the action of dilute hydrochloric acid on the metals; an order of activity based on the above three properties; the displacement of a metal low down the series from its compounds by a metal higher up; the decrease in stability of the compounds of the metals down the series.

*Theme 7: Acids and Bases*

Action of acids (mineral acids, ethanoic acid, lemon juice) on indicators (litmus, phenolphthalein, methyl orange, Universal Indicator); action of metals (magnesium, aluminium, iron, lead, copper) on acids (hydrochloric and sulphuric acids); action of acids on carbonates and bicarbonates (sodium carbonate, calcium carbonate, copper carbonate, sodium bicarbonate, zinc carbonate, magnesium carbonate); properties of bases and alkalis (potassium, sodium, calcium and ammonium hydroxides); precipitation of hydroxides (iron II, iron III, copper II, zinc and magnesium hydroxides) from solutions of salts, using sodium hydroxide and potassium hydroxide solutions; neutralisation and soil acidity.

*Theme 8: Nitrogen and Ammonia*

Preparation of nitrogen from ammonium chloride and sodium nitrite solutions; properties of nitrogen (does not burn, insoluble, neutral, magnesium burns in it); fixation of nitrogen and the Nitrogen Cycle; the Haber Process; preparation of ammonia from sodium hydroxide and ammonium sulphate; properties of ammonia (solubility in water, alkalinity, precipitation of insoluble hydroxides) action of heat on ammonium salts (ammonium chloride, ammonium carbonate, ammonium nitrate). Uses

*Theme 9: Atoms and Ions*

The particles in the atom (electron, proton, neutron); the arrangement of particles in the atom (hydrogen, helium); the formation of ions by the loss or gain of electrons; the formation of ionic compounds by the transfer of electrons.

*Theme 10: Some Chemical Calculations*

Relative atomic mass on the hydrogen standard; formula mass; calculation of formula mass; calculation of percentage composition.

**MATTER AND ENERGY**

| | | |
|---|---|---|
| *Theme 1:* | *Measurement of Length, Area and Volume* | Use of metre rule, burette and measuring cylinder. |
| | Mass | A property depending on inertia of a body. |
| | Density | Determination by measurement and weighing for liquids and regular solids<br>*and*<br>by displacement (immersion) for irregular solids. |
| | Moment of a force | Illustrated by simple examples with forces applied to balanced levers (oblique forces excluded). |
| *Theme 2:* | *Force* | Effects of forces. (Qualitative only). |
| | Work | Examples of work done by and against forces. |
| | Energy | Energy acquired when work is done. Kinetic and potential energy. |
| | Power | Rate of working. |
| | The joule, J.<br>The watt, W.<br>The newton, N. | |
| *Theme 3:* | *Temperature* | Celsius (Centigrade scale). Kelvin scale. |
| | Measurement of temperature | Liquid-in-glass thermometer (mercury and alcohol). |
| | Fixed points | Determination of ice point and steam point. |
| | The clinical thermometer | Its temperature range. |
| *Theme 4:* | *Thermal Expansion of Solids, Liquids and Gases* | Effects and application. (The working of thermostat excluded).<br>Ideas of relative orders of magnitude. (Gas laws excluded). |

### *Theme 5: Heat as a Form of Energy*

| | |
|---|---|
| The unit of heat | The joule, J. |
| Heat capacity, C | Definition in terms of units. |
| Specific heat capacity, S | Simple numerical problems may be set. (Experimental determination excluded). |
| Latent heats of fusion and vaporisation | Definitions only. (Excluded - problems involving latent heats and the experimental determination). |

### *Theme 6: Transfer of Heat*

| | |
|---|---|
| Conduction, convection and radiation | Qualitative explanation illustrated by simple experiments. |

### *Theme 7: Magnets*

| | |
|---|---|
| Simple phenomenon of magnetism | Properties of magnets, magnetic induction. Distinction between magnets and unmagnetized substances. Distinction between magnetic and non-magnetic substances. |
| Method of magnetization and demagnetization. | |

### *Theme 8: Electrostatics*

| | |
|---|---|
| Introduction to the idea of static charge | Simple experiments with charges (friction). (Excluded induction). |
| Positive and negative charges | |

### *Theme 9: Simple or Voltaic Cell*

| | |
|---|---|
| | Include polarization. |
| Dry cell | Simple structure only. |
| The accumulator | As a storage cell. (Without chemistry of charging and discharging). |

### *Theme 10: Current Electricity*

| | |
|---|---|
| The ampere | The unit in which current is measured. A precise definition is not expected. Use of an ammeter to measure current. |
| Development of concept of electromotive force | Using the flow of water in pipes as a rough model. |
| The volt | The unit in which the potential difference is measured. Use of a voltmeter to measure the potential difference. |
| Power | The relation between the volt, the ampere and the watt is expected. |
| Ohm's law | Application to single conductors and whole circuits. |
| The Ohm | The unit of resistance. |
| Resistors in series and parallel | Calculation of effective resistance expected. |

*Theme 11: Effects of an Electric Current*

| | |
|---|---|
| Heating effect | Practical applications - electric irons, lamps. |
| Chemical effect | Distinction between electrolytes and non-electrolytes.<br>Electrolysis of water. |
| Magnetic effect | Nature of the magnetic field for straight wire, soleroid. |
| Applications | Electromagnets, the electric bell. (Excluding the details in the construction of electric bell). |

*Theme 12: Light*

| | |
|---|---|
| Rays, the rectilinear propagation of light | Formation of shadow, eclipses, the pin-hole camera.<br>(Excluded - the working of a photographic camera). |

| | |
|---|---|
| *Theme 13: The Reflection of Light Laws of Reflection* | Position and characteristics of the image formed by a plane mirror.<br>(Excluded - the working of the periscope and the kaleidoscope). |

*Theme 14: Sound*

| | |
|---|---|
| Production of sound by vibrating systems | Violin strings, tuning forks. |
| Transmission of sound | Necessity for a material medium.<br>(Excluded the necessary experiment to prove it).<br><br>Questions will not be set on the determination of speed of sound, reflection of sound, etc. |

350 Index Number ............

# APPENDIX C

Mauritius Institute of Education

THE CERTIFICATE OF JUNIOR SECONDARY EDUCATION EXAMINATION

*INTEGRATED SCIENCE*

(PAPER I)

*Time: 1 hour*

SPECIMEN PAPER

1. *Do not open this booklet until you are told to do so.*
2. *Write your Index Number on the question paper.*
3. *This booklet contains FORTY questions (nine pages). Each sentence has been given* FOUR *possible answers - A, B, C and D. Choose the* CORRECT *answer and put the letter for it on the line at the right-hand side.*

**ANSWER ALL THE QUESTIONS.**

180

1. Hydrogen can be prepared from

A copper and dilute hydrochloric acid.
B copper carbonate and dilute sulphuric acid.
C zinc and dilute sulphuric acid.
D copper sulphate and dilute nitric acid.

*Answer* ...........

2. A metal *M* has a valency of 3, the formula of its oxide is

A $M_2O_3$

B $M_3O_2$

C $M^2O^3$

D $M^3O^2$

*Answer* ...........

3. Which metal will replace hydrogen from dilute hydrochloric acid but will *NOT* replace zinc?

A magnesium.
B lead.
C copper.
D iron.

*Answer* ...........

4. When a candle has been lit for some time it becomes lighter. This is because the candle wax

A evaporates.
B changes into a liquid.
C is completely destroyed.
D changes into a gas which burns.

*Answer* ...........

5. Where would you expect to find cockroaches?

A in a dark food shop.
B near a pool of water.
C near the shore.
D in an empty cold store.

*Answer* ...........

6. What is the part of saliva which is responsible for the digestion of starch?

A an enzyme.
B an oil.
C a vitamin.
D an amino acid.

*Answer* ...........

7. Which *one* of the following practices is *not* carried out in Mauritius?

A overhead irrigation.
B wheat cultivation.
C ploughing with the help of tractors.
D agricultural training.

*Answer* ...........

8. Which of the following gases is a pollutant of air?

A nitrogen.
B carbon dioxide.
C sulphur dioxide.
D oxygen.

*Answer* ...........

9. Which of the following forms of energy on Earth *cannot* be traced back to the sun's energy?

A energy from food.
B energy from fuel.
C hydroelectric energy.
D atomic energy.

*Answer* ...........

10. The mass of a body is the

A space occupied by the body.
B ratio of density to volume of the body.
C amount of inertia in the body.
D number of paces along the length of the body.

*Answer* ...........

11. The best description of what happens to a bimetallic strip in a fire alarm when heated is

A an increase in length which is useful.
B an increase in length which is a nuisance.
C a decrease in length which is useful.
D a decrease in length which is a nuisance.

*Answer* ...........

12. Rubidium hydroxide has alkaline properties. It will therefore

A be insoluble in water.
B dissolve in water to give a solution which turns blue litmus red.
C dissolve in water to give a solution which turns red litmus blue.
D dissolve in water to give a solution which is neutral to litmus.

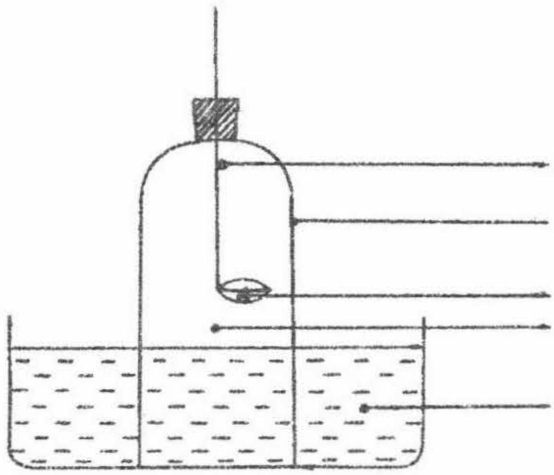
*Answer* ...........

13. River water is polluted if it is found to be

A full of water-weeds.
B covered with oil.
C very muddy.
D full of water-weeds and very muddy.

*Answer* ...........

14.




When the solid element *X* was burned in the above apparatus, it formed a solid oxide. Which *one* of the following would you expect?

A the mass of gas in the bell-jar would remain the same.
B the mass of solid in the deflagrating spoon would remain the same.
C the total mass of apparatus and its contents would remain the same.
D the total mass of the apparatus and its contents would be less than it was before.

*Answer* ...........

15. In which of the following groups are all the animals devoid of backbone?

A worm, caterpillar, bird.
B rat, caterpillar, ant.
C worm, ant, caterpillar.
D lizard, caterpillar, ant.

*Answer* ...........

16. Which of the following does a tree have but which a shrub does not have?

A roots.
B leaves.
C trunk.
D flowers.

*Answer* ...........

17. If woodlice are able to choose between a dry and moist atmosphere they will

A move to the dry atmosphere.
B move to the moist atmosphere.
C be indifferent to the humidity.
D keep changing from moist to dry and back.

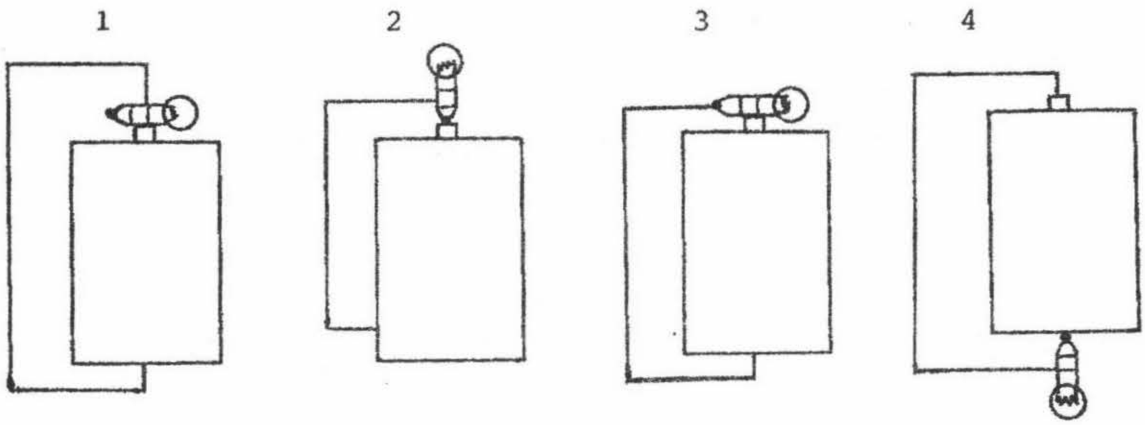
*Answer* ...........

18. If some clear sea water is evaporated to dryness in a basin, the basin will be found to contain

A a brown powder.
B a white crystalline substance.
C a large white crystal.
D nothing.

*Answer* ...........

19.




In the pictures above which bulbs will light up?

A 1, 2, 3, 4.
B 2, 3, 4.
C 3, 4.
D 4.

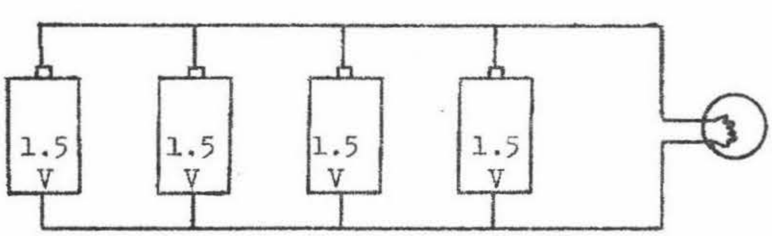
*Answer* ...........

20. Some herbicide (a poison used to kill weeds) poured into a river in Mauritius

A has no effect on whales in Antartica because Antartica is too far away.
B affects whales in Antartica because poisons once they reach the sea are spread by ocean currents and affect all living things.
C reaches Antartica but has no effect on whales as herbicides only poison weeds.
D stays in the river and will have nothing to do with whales or Antartica.

*Answer* ...........

21.




The voltage provided by the batteries to the bulb in the picture is

A 6 *V*.
B 3 *V*.
C 1·5 *V*.
D 0 *V*.

22. A thermometer measures

A amount of heat.
B expansion of mercury.
C expansion of glass.
D degree of hotness.

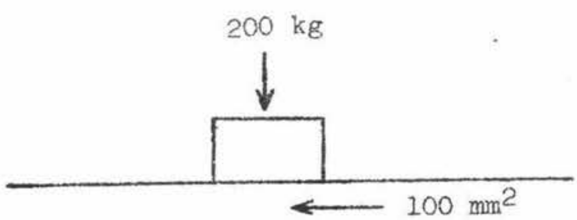
*Answer* ...........

23. When someone walks through the light beam from a cineprojector, a shadow of his head passes across the screen. The shadow is black because

A the head stops light from reaching the screen.
B the projector lamp is very bright.
C the light beam is converging onto the screen.
D the head reflects back all the light.

*Answer* ...........

24.




In the picture above the pressure in Kg per $mm^2$ is

A 0·5
B 2
C 100
D 300

*Answer* ...........

25. A plant grown in a solution that does *not* contain nitrogen compounds shows poor growth because nitrogen is essential for

A the making of humus.
B the formation of proteins.
C the production of sugar.
D the nitrogen-fixing bacteria in the roots.

*Answer* ...........

26. Why is it advisable to use renewable fuels?

A they supply more joules per gramme.
B they will make the non-renewable fuels last forever.
C renewable fuels cause less pollution.
D there is a limited supply of non-renewable fuels.

*Answer* ...........

27. A gas which is *not* very reactive and a counts for about 80 per cent of the atmosphere is

A oxygen.
B hydrogen.
C nitrogen.
D carbon dioxide.

*Answer* ...........

28. An impurity is dissolved in a liquid. Which is the best method of obtaining a pure sample of that liquid?

A distillation of the solution.
B crystallisation of the impurity.
C precipitation of the impurity.
D filtration of the solution.

*Answer* ...........

29. Arteries are vessels carrying blood from

A heart to lungs only.
B heart to various parts of the body.
C various organs to liver.
D various organs to heart.

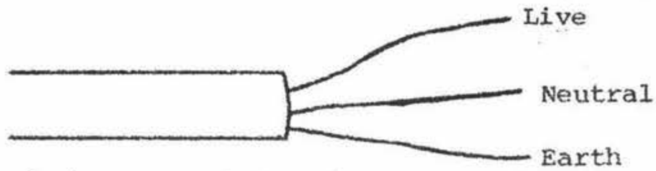
*Answer* ...........

30. Pick out the odd word from the list below

A ovary.
B stigma.
C ovule.
D testis.

*Answer* ...........

31.

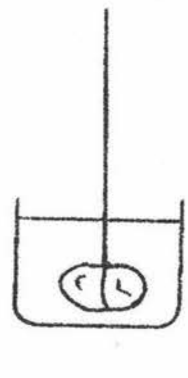



Which are the correct colours for the mains wires in the picture above?

| | Live | Neutral | Earth |
|---|---|---|---|
| A | red | green | black |
| B | brown | green-yellow | blue |
| C | red | blue | green |
| D | brown | blue | green-yellow |

*Answer* ...........

32.



A heavy stone is suspended in water as shown in the picture. Which of the statement below is correct?

A the stone weighs the same as it does in the air.
B the upthrust equals the force of gravity.
C the stone weighs more than it does in the air.
D the upthrust is less than the force of gravity.

*Answer* ...........

33. An electric kettle full of cold water is heated from $20^{o}C$ to $65^{o}C$ in two minutes. After a further two minutes, the water in the kettle will be

A at $110^{o}C$.
B boiling.
C changed completely into steam.
D at $85^{o}C$.

*Answer* ............

34. Tea grows well in the Midlands and sugar cane in the Northern Plain. This is an example of the way in which

A plants adapt themselves to their surroundings.
B pressure varies with height above sea-level.
C climate affects the growth of plants.
D fertilizers affect the growth of plants.

*Answer* ............

35. A plant needs carbon dioxide, water and sunlight to make starch. From this information we can infer that the starch is made from

A carbon only.
B hydrogen and oxygen.
C carbon and oxygen.
D carbon, oxygen and hydrogen.

*Answer* ............

36. Carbon dioxide is useful in fire extinguishers because

A it is easily solidified.
B solid carbon dioxide is very cold.
C carbon dioxide does not support burning.
D carbon dioxide contains oxygen.

*Answer* ............

37. If a body is accelerating uniformly this is because the force on it is

A zero.
B constant.
C increasing with time.
D decreasing with time.

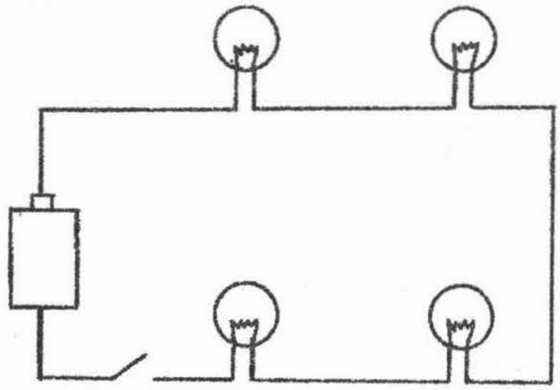
*Answer* ............

38. Which of the following is *not* a renewable natural resource?

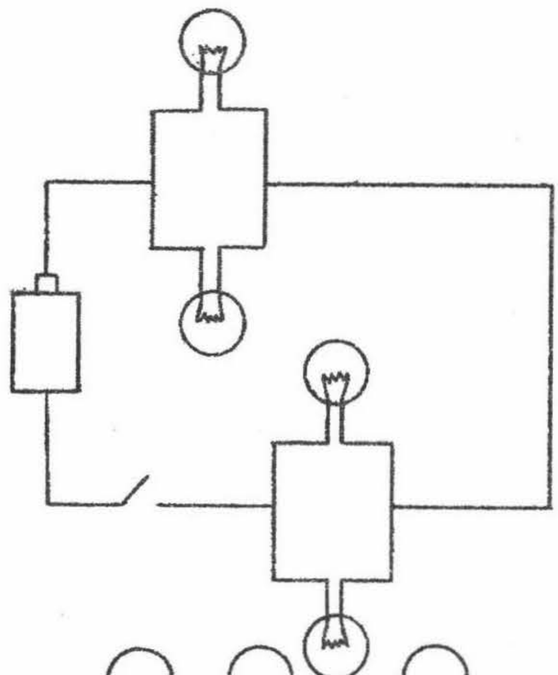
A trees.
B water.
C soil.
D fish.

*Answer* ............

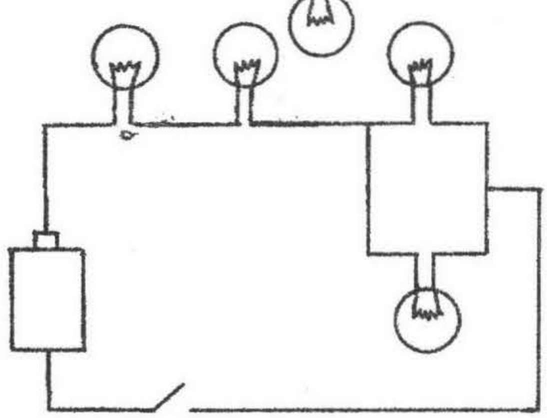
39. In which picture below are there two bulbs in series and two bulbs in parallel?



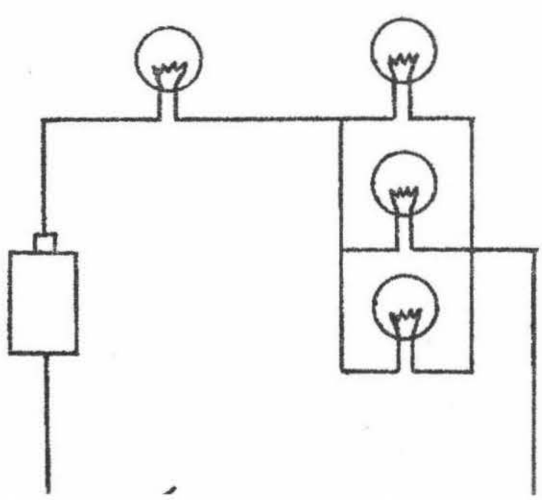
A



B



C



D

40.


A gardener placed some soil in a can. He then pressed the solid down thereby increasing the soil's density. From the above, which statement best describes the meaning of the term density?

A the mass of soil increased.
B the mass of soil decreased.
C the volume of soil and the mass decreased.
D the volume of soil decreased but the mass remained the same.

*Answer* ............

189

350 **Index Number** ............

Mauritius Institute of Education

THE CERTIFICATE OF JUNIOR SECONDARY EDUCATION EXAMINATION

*INTEGRATED SCIENCE*

(PAPER II)

*Time: 1½ hours*

SPECIMEN PAPER

1. *Do not open this booklet until you are told to do so.*
2. *Write your Index Number on the question paper.*
3. *This booklet contains TWELVE questions (six pages).*
4. *Write all your answers clearly on the question paper itself.*

**ANSWER ALL THE QUESTIONS.**

190

## *Matter and Energy*

1. (a) A mercury thermometer is graduated so that the lower fixed point and upper fixed point are marked on it.

Write down these values in $^{o}C$.

Lower fixed point ............................

Upper fixed point ............................

(b) What happens to the volume when a solid or liquid or gas becomes hotter?

..............................................................

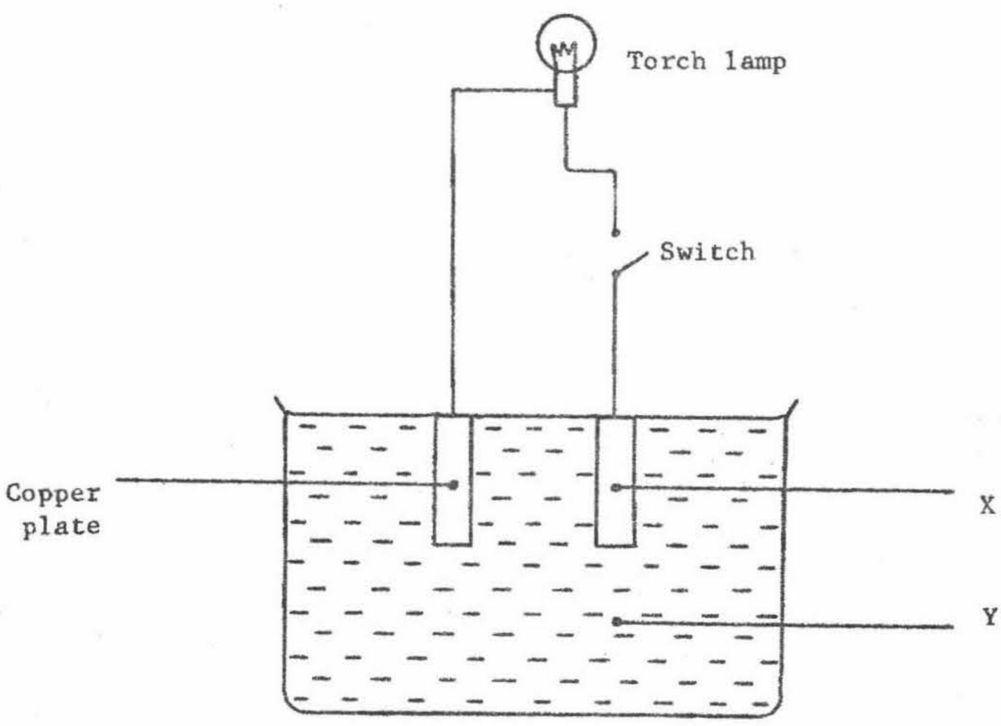
Give **ONE** example where this heating effect is used.

..............................................................

(c) Why does your hand feel cool after some acetone or ether has been placed on it?

..............................................................

2. (a) The diagram represents the simple electric cell *(voltaic cell)*. Label the missing parts.




X is ..................................

Y is ..................................

(b) For an electric cell to drive a current through a resistance wire, what must the cell exert?

....................................................................

If *three* such resistance wires are placed in series with the above electric cell, what happens to the current now?

....................................................................

(c) Name *two* effects of an electric current.

....................................................................

....................................................................

3. (a) Suppose you are working as a nurse.

You have just taken the temperature of a patient using a clinical thermometer.

How do you re-set the thermometer?

....................................................................

(b) You are given a mixture of pieces of copper, wood, iron, glass, brass and aluminium.

How can you remove the pieces of iron quickly?

....................................................................

Name *two* precautions you must take when measuring accurately the length of your book with a ruler.

....................................................................

....................................................................

4. (a) In view of the energy crisis, alternative sources of energy are required.

Can you suggest *three* inexhaustible sources?

....................................................................

....................................................................

....................................................................

(b) A businessman wants to buy an engine to be used in his factory.

Name *two* factors upon which he can base his decision for the purchase.

....................................................................

....................................................................

192

## *Matter and Life*

5. (a) What is respiration?

.....................................................................

.....................................................................

.....................................................................

Through which organs do the following animals obtain oxygen for respiration:

(b) Rabbit ................................

(c) Tilapia ................................

(d) Adult Toad ................................

6. (a) Water exposed to air contains less than 1% oxygen. Blood exposed to air contains about 20%.

What do these figures tell us about *one* use of blood?

.....................................................................

.....................................................................

.....................................................................

Apart from its connection with breathing and respiration name *three* functions of blood.

(b) .....................................................................

(c) .....................................................................

(d) .....................................................................

7. You are provided with *three* unlabelled tubes, containing respectively glucose solution, starch solution and water.

Which test would you carry out to find out which is which?

First test you would do ................................................

.....................................................................

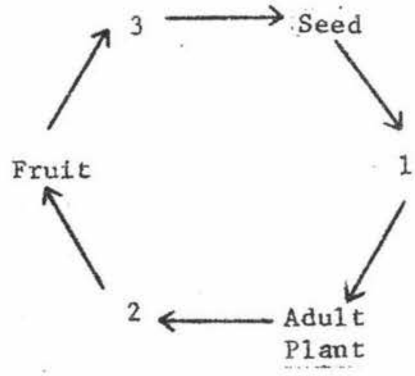
Second test you would do ................................................

.....................................................................

Conclusion you would draw ................................................

.....................................................................

8. (a) Arrange the following in correct order - *bud / seed / flower / fruit / adult plant / seedling.*




1. ..............................

2. ..............................

3. ..............................

(b) Explain in not more than *five* lines how a knowledge of human reproduction help in population control.

.............................................................................

.............................................................................

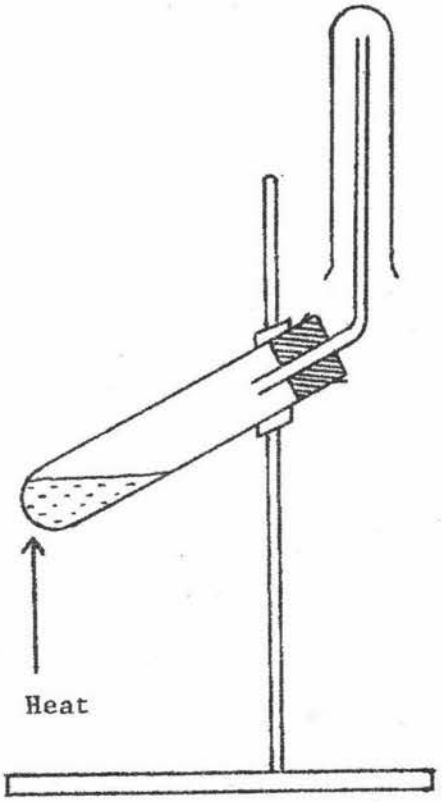
.............................................................................

.............................................................................

.............................................................................

*Matter and its Reactions*

9. The diagram represents the apparatus used to prepare and collect a few test tubes of ammonia.



(a) Name *two* substances which can be used to prepare the gas.

(i) ........................ (ii) ..........................

(b) The test tube is inverted because ammonia is .................

...............................................................

(c) When a solution of ammonia in water is added to iron (II) sulphate solution, a ........... precipitate of ........... is formed.

10. Choose from the following list of substances:

| | |
|---|---|
| Sea water | Iron |
| Mercury | Sodium nitrite |
| Sulphur | Sulphur dioxide |
| Ammonium chloride | |

Each substance may be used ONCE or MORE THAN ONCE.

(a) An element which is a liquid metal.

...............................................................

(b) A mixture of substances.

...............................................................

(c) *One* acidic gas which is formed by burning a non metal in air.

...............................................................

(d) *Two* solid elements which combine on heating.

...............................................................

(e) *Two* substances which give nitrogen when heated.

...............................................................

11. A green powder *X* when heated gave a colourless gas *Y* which turned lime water milky. A residue *Z* was obtained which dissolved in dilute sulphuric acid to give a blue solution. *X* reacts with dilute sulphuric acid to give the same gas.

(a) What is the colour of the residue *Z* and give its formula.

...............................................................

(b) Write balanced equations for the following:

(i) *Z* and dilute sulphuric acid.

..........................................................

(ii) *X* and dilute sulphuric acid.

..........................................................

(iii) Action of heat on *X*.

..........................................................

12. (a) Give *two* differences in properties between diamond and graphite.

(i) ..........................................................

..........................................................

(ii) ..........................................................

..........................................................

(b) You are provided with *three* test tubes containing carbon dioxide, carbon monoxide and hydrogen.

Describe *briefly* how you would find out which was which.

..........................................................

..........................................................

..........................................................

..........................................................

..........................................................

APPENDIX D

MAURITIUS INSTITUTE OF EDUCATION

End of Year Evaluation - FORM I

INTEGRATED SCIENCE (1¼ hours)

21st October 1976

Name : ____________________

School : ____________________

Form : ____________________

## SECTION A

Answer ALL Questions

1. In each question, there are four alternative answers.
2. Each answer has a letter opposite, in the right hand margin.
3. Read the answer carefully and with a pen, cross out the letter in the right side margin, opposite the correct answer.
4. Do not cross out more than one letter, or you will receive no mark.

### QUESTION 1

ANSWER HERE

Water is boiled in a tin which is then sealed and cooled in a sink of cold water. The tin collapses noisily. This happens because

A. the water in the tin boils — A

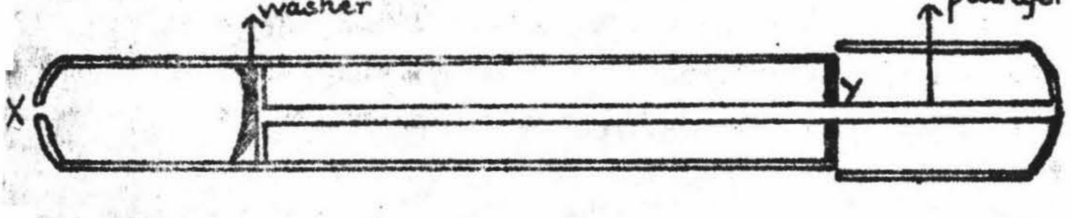
B. the pressure outside the tin is greater than that inside the tin — B

C. the pressure outside the tin is less than that inside the tin — C

D. the steam has escaped from the tin — D

### QUESTION 2

The drawing below represents a bicycle pump.




The plunger serves to :

A. push air out of X — A

B. push air out of Y — B

C. plunge the pump — C

D. hold the washer — D

**QUESTION 3** **ANSWER HERE**

A barometer measures

| | | |
|---|---|---|
| A. | air pressure | A |
| B. | blood pressure | B |
| C. | the height of the mercury column | C |
| D. | air temperature | D |

**QUESTION 4**


Most rain will fall on

| | | |
|---|---|---|
| A. | the sea | A |
| B. | the coast | B |
| C. | the mountain | C |
| D. | the plain | D |

**QUESTION 5**

Sea-breezes blow

| | | |
|---|---|---|
| A. | far from the coast | A |
| B. | from the sea to the land | B |
| C. | from the land to the sea | C |
| D. | at night | D |

**QUESTION 6**

The approximate composition of ordinary air is

| | | |
|---|---|---|
| A. | Nitrogen 79%; Oxygen 16%; Carbon dioxide 4% | A |
| B. | Nitrogen 79%; Oxygen 20%; Carbon dioxide 0.04% | B |
| C. | Nitrogen 20%; Oxygen 79%; Carbon dioxide 0.4% | C |
| D. | Nitrogen 79%; Oxygen 4%; Carbon dioxide 17% | D |

**QUESTION 7**

Which would be the <u>easiest</u> to compress (squeeze) into a 900 $cm^3$ bottle?

| | | |
|---|---|---|
| A. | 1000 $cm^3$ of water | A |
| B. | 1000 $cm^3$ of wood | B |
| C. | 1000 $cm^3$ of air | C |
| D. | 1000 $cm^3$ of ice | D |

QUESTION 8 ANSWER HERE

John blew up a balloon, tied it tightly, and put it into a cold refrigerator. One hour later he removed the balloon and saw that it had become smaller. This probably happened because

A. the air in the balloon contracted A

B. the air in the balloon became less dense B

C. water condensed on the outside of the balloon C

D. particles of air escaped from the balloon D

QUESTION 9

The air we breathe out

A. contains no oxygen A

B. is almost pure carbon dioxide B

C. contains more oxygen than unbreathed air C

D. contains more carbon dioxide than unbreathed air D

QUESTION 10

Some flour is burnt in a spoon in a gas jar. When some lime water is poured into the jar, it goes cloudy. From this experiment alone, you learn that

A. flour contains carbohydrate A

B. carbohydrates contain starch B

C. when flour burns, carbon dioxide is formed C

D. all carbohydrates burn in air to form carbon dioxide D

Total marks : 40

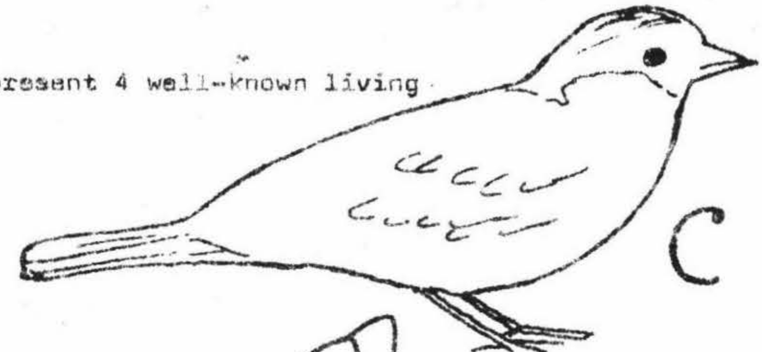
199

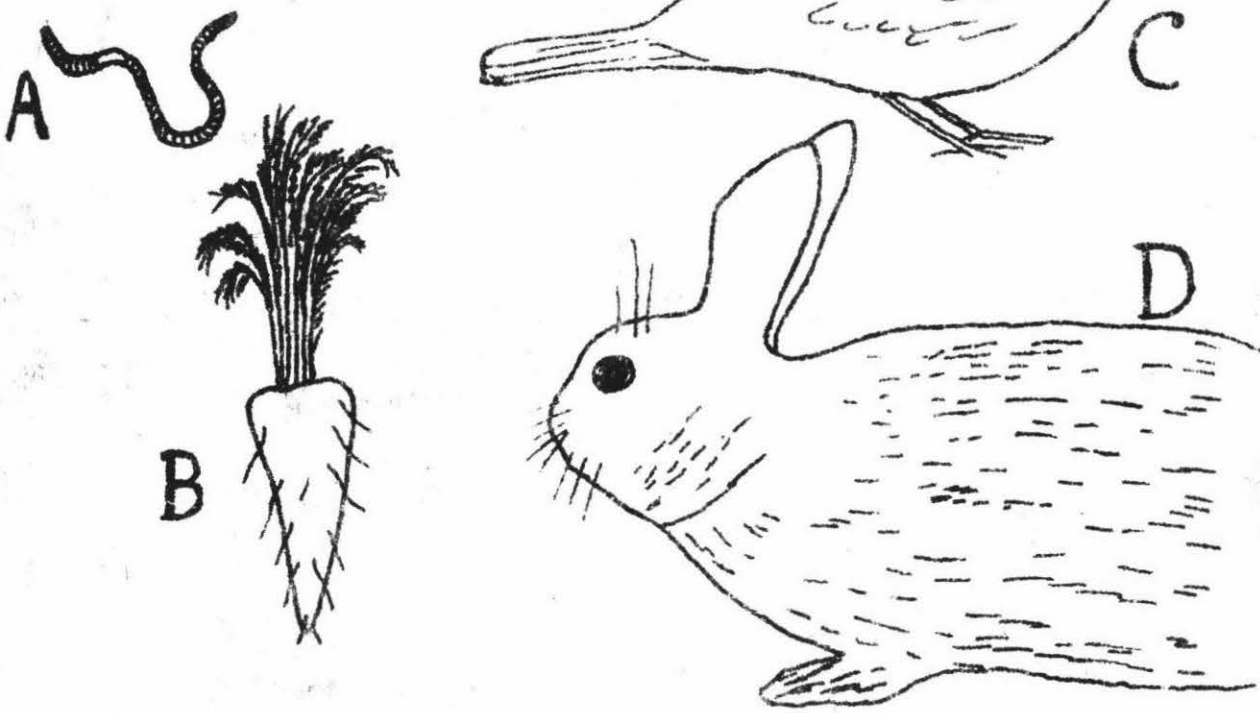
## SECTION B

Answer All Questions

### QUESTION 1

Diagrams A, B, C and D represent 4 well-known living things




(a) Fill in the table below for each of living things A, B, C and D. Use ticks [✓] wherever necessary

| | A | B | C | D |
|---|---|---|---|---|
| 1. It makes its own food | | | | |
| 2. It eats seeds and insects | | | | |
| 3. It eats plants | | | | |
| 4. It feeds on decaying plants | | | | |
| 5. It is covered with fur | | | | |
| 6. It is covered with feathers | | | | |
| 7. It is covered with scales | | | | |
| 8. It is covered with none of the above | | | | |
| 9. It does not move about | | | | |
| 10. It moves using wings | | | | |
| 11. It moves using legs | | | | |
| 12. It moves using fins | | | | |
| 13. It moves by creeping | | | | |

(b) Animal A is useful because

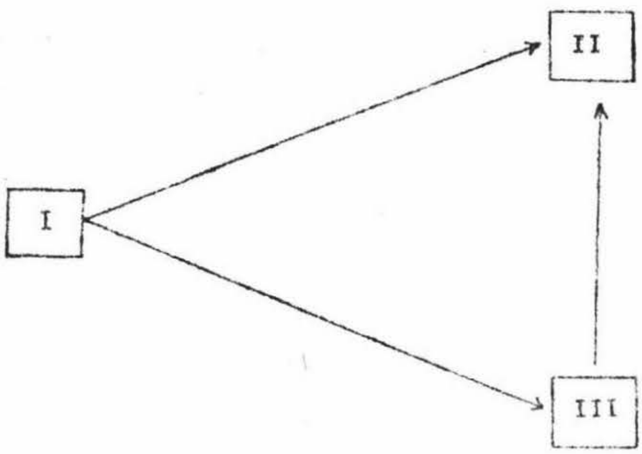
It keeps soil aerated ☐
It keeps soil warm ☐
It destroys germs ☐

(c) This is an example of a food relationship :

grass ——→ goat ——→ man

The diagram below represents a food relationship grouping <u>three</u> of the following :

A, B, C, D and man




Which three? I : .....

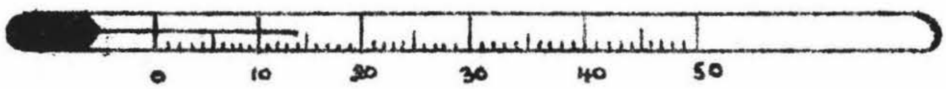
II : .....

III : .....

20 marks

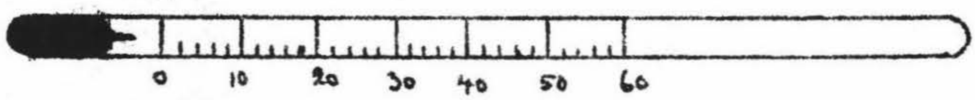
QUESTION 2:

(a) What is the temperature reading on the thermometer below?

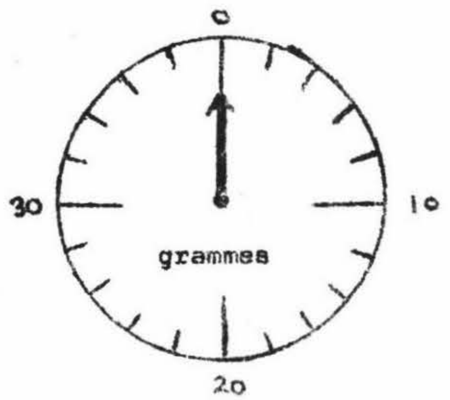



ANSWER : ............................................

(b) Complete the mercury column of the thermometer up to 15°C.




(c) How many grammes is recorded for each of the divisions on the balance scale below?




ANSWER : ............................................

(d) Here are two pendulums A and B.

Which pendulum, A or B, will make the most swings in one minute?

ANSWER : ............................................

202

(e) Pendulum X takes 15 seconds to make 10 swings and pendulum Y takes 20 seconds to make 10 swings.

Pendulum Y takes longer because

A. the weight of the bob is bigger ☐

B. the size of the swing is greater ☐

C. the length of the string is longer ☐

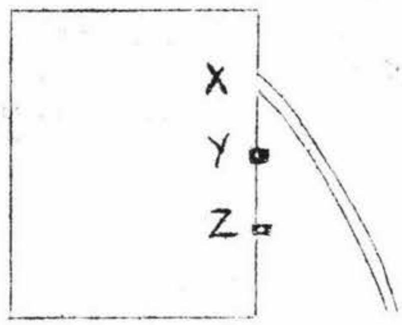
(Place a tick ☑ in the square opposite the right answer)

12 marks

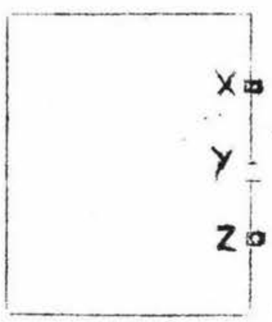
QUESTION 3

A tall tin full of water has three holes X, Y and Z. Each hole is closed with a cork.

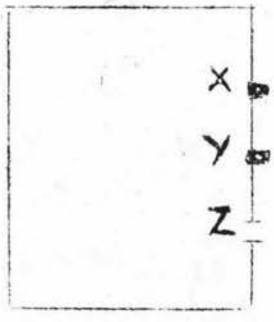
Water comes out in a jet, as shown, when the cork at X is removed.



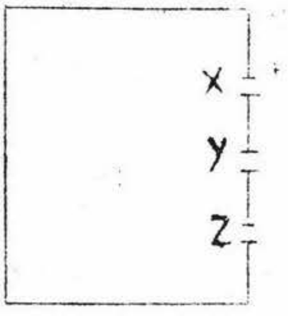

(i) Complete the diagram to show the jet of water from hole Y when holes X and Z only are closed.




(ii) Complete the diagram to show the jet of water from hole Z when holes X and Y only are closed.



(iii) Complete the diagram to show the 3 jets of water from holes X, Y and Z with all the corks removed.




(iv) The difference between the jets from holes X and Z is due to

A. the pressure at Z being greater than the pressure at X ☐

B. the pressure at X being greater than the pressure at Z ☐

C. the hole X being bigger than the hole Z ☐

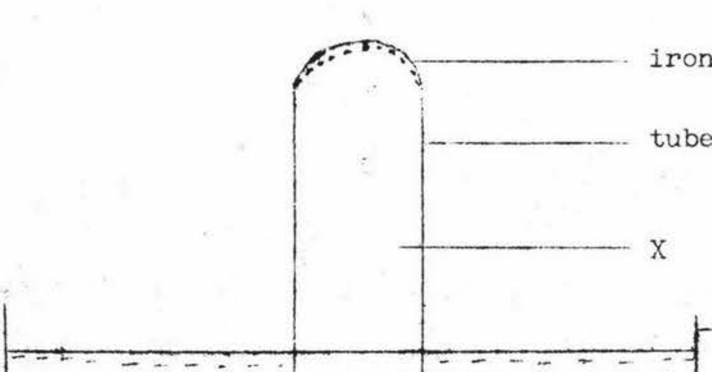
D. the hole Z being bigger than the hole X ☐

(Place a tick ✓ in the square opposite the right answer)

14 marks

## QUESTION 4

Iron filings were sprinkled into a wet tube, then the tube was inverted over a basin of water, as shown in the diagram below.



Place a tick ✓ in the square opposite the correct answer.

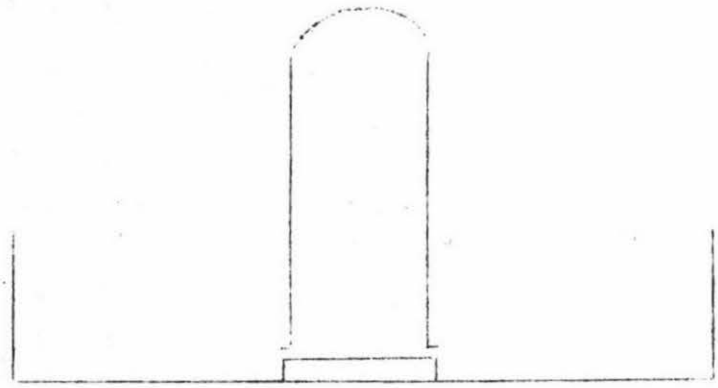
(a) The substance X in the tube is

(i) oxygen

(ii) water

(iii) air

(b) Complete the diagram below to show the changes which occurred after the apparatus had been left aside for a few days.



(c) Place a tick ✓ against the correct statement in the examples below.

(i) The change in (b) occurred because

some of X escaped from the tube

some of X reacted with the iron filings

some of X reacted with the iron filings

(ii) The iron filings changed colour from

grey to green

grey to reddish brown

white to grey

(iii) The change which occurred was

a chemical change

a physical change

(iv) The name given to the change is

solution ☐

rusting ☐

evaporation ☐

(v) Iron can be protected from the above change by

hammering ☐

painting ☐

heating ☐

14 marks

Total marks - Section B - 60

# APPENDIX E

Table 8: 'New' Behaviour - Test Content Grid

(with overt behaviour specifications)

| TEST CONTENT | Behaviour (objectives) Ques. | | Knowledge Understanding rec. | app. | inter. | Skills (process) obs. | meas. | class. | sel. | inf. | com. | Marks Allotted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SECTION A | 1 | | | ✓ | | | | | | | | 4 |
| | 2 | | | | | ✓ | | | | | | 4 |
| | 3 | | ✓ | | | | | | | | | 4 |
| | 4 | | | | | | | | | ✓ | | 4 |
| | 5 | | | | | ✓ | | | | | | 4 |
| | 6 | | ✓ | | | | | | | | | 4 |
| | 7 | | | | | | | | ✓ | | | 4 |
| | 8 | | | | | | | | | ✓ | | 4 |
| | 9 | | ✓ | | | | | | | | | 4 |
| | 10 | | | | | | | | | ✓ | | 4 |
| SECTION B | 1 | (a) | | ✓ | | | | | | | | 13 |
| | | (b) | | | ✓ | | | | | | | 1 |
| | | (c) | | | | | | ✓ | | | | 6 |
| | 2 | (a) | | | | | ✓ | | | | | 2 |
| | | (b) | | | | | | | | | ✓ | 2 |
| | | (c) | | | | | | | | | ✓ | 2 |
| | | (d) | | | ✓ | | | | | | | 3 |
| | | (e) | | | | | | | ✓ | | | 3 |
| | 3 | (i) | | ✓ | | | | | | | | 3 |
| | | (ii) | | ✓ | | | | | | | | 3 |
| | | (iii) | | ✓ | | | | | | | | 4 |
| | | (iv) | | ✓ | | | | | | | | 4 |
| | 4 | (a) | ✓ | | | | | | | | | 2 |
| | | (b) | | | | | | | | | ✓ | 2 |
| | | (c)(i) | ✓ | | | | | | | | | 2 |
| | | (ii) | ✓ | | | | | | | | | 2 |
| | | (iii) | ✓ | | | | | | | | | 2 |
| | | (iv) | ✓ | | | | | | | | | 2 |
| | | (v) | ✓ | | | | | | | | | 2 |
| MARKS per behaviour specification | | | 24 | 31 | 4 | 8 | 2 | 6 | 10 | 9 | 6 | 100 |
| | | | 59 | | | 41 | | | | | | |

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