DOCUMENT RESUME

ED 373 995 SE 054 768

TITLE Future Content in Science and Technology Education at Secondary Level. Proceedings of the UNESCO PROAP/APEID Regional Workshop for the Development of Science Education at the Secondary Level with Special Reference to Futures Content (Beijing, People's Republic of China, November 29-December 5, 1989).

INSTITUTION United Nations Educational, Scientific and Cultural Organization, Bangkok (Thailand). Principal Regional Office for Asia and the Pacific.

PUB DATE 92

NOTE 92p.

PUB TYPE Collected Works - Conference Proceedings (021)

EDRS PRICE MF01/PC04 Plus Postage.

DESCRIPTORS *Course Content; *Educational Change; *Foreign Countries; *Science Education; Secondary Education; Workshops

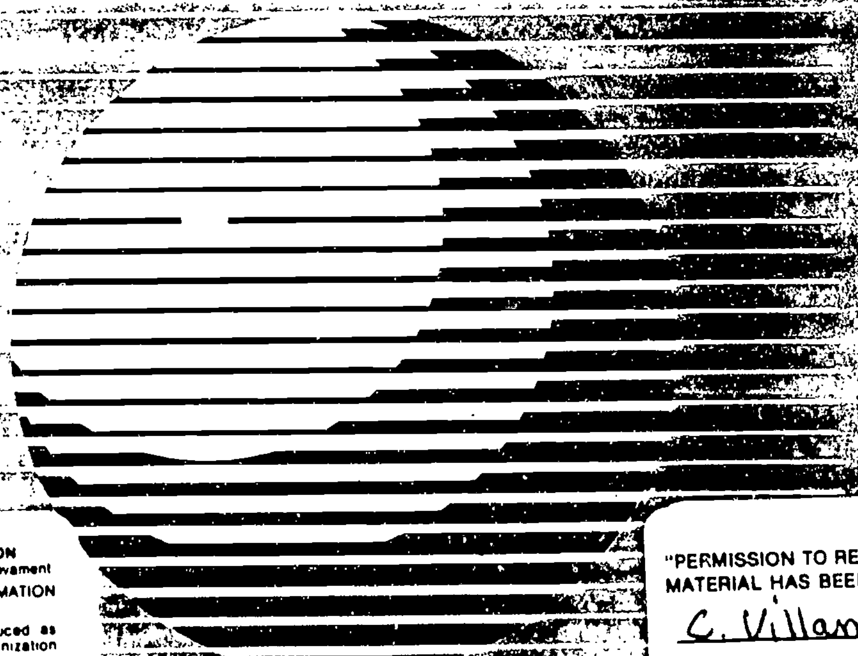
ABSTRACT

In order to improve science education for students, it is necessary to look ahead at long term projects geared toward the improvement of science education and the specific content that must be taught today to prepare students for future science endeavors. To provide a forum for this discussion, The three major components of the workshop were as follows: (1) country experiences in regard to new trends in science and technology education at the secondary level, future content and curricular designs in science and technology education at the secondary level, and current status of the developmental work in this regard; (2) future content, its justification and its analysis; and (3) potential sources for reference and consultation, possible learning/teaching activities, investigations and experiments for the secondary level in regard to this content, and likely implementation difficulties. Chapter one, "Country Comments," includes brief summaries of the thinking, priorities, strategies, design, and content being considered nationally for the future science and technology education at secondary levels of seven of the participating countries (People's Republic of China, Indonesia, Malaysia, Mongolia, Philippines, Thailand, and Socialist Republic of Vietnam). Chapter two, "Future Content" undertakes the task of indicating the kinds of content analyses countries would need to undertake prior to entering the complex tasks of curriculum development. In chapter three, "Learning/Teaching of Future Content" a biological science and physical science group focus on the learning and teaching of the new science and technology content, and on linking the existing content to the new content. The fourth chapter, "Recommendations" presents the list of common problems faced by participating countries and makes specific recommendations for future aid by UNESCO. (ZWH)

APEID

Asia and the Pacific Programme of Educational Innovation for Develop...

Future Conte... in Science and Technolog... Education a... Secondary Le...



UNESCO PRINCIPAL REGIONAL OFFICE FOR ASIA AND THE PACIFIC ...KOK

UNESCO Regional Workshop for the Development of Science Education at the Secondary Level with Special Reference to Futures Content, Beijing, 29 November - 5 December 1989.

Future content in science and technology education at secondary level. Bangkok, 1992.

81 p. (Asia and the Pacific Programme of Educational Innovation for Development)

1. SCIENCE EDUCATION – ASIA/PACIFIC. 2. SECONDARY SCHOOL CURRICULUM – ASIA/PACIFIC. 3. TECHNICAL EDUCATION – ASIA/PACIFIC. I. UNESCO. Principal Regional Office for Asia and the Pacific. II. Title. III. Series.

507
372.3

SE

APEID

Asia and the Pacific Programme of Educational Innovation for Development

Future Content in Science and Technology Education at Secondary Level

UNESCO

4

UNESCO PRINCIPAL REGIONAL OFFICE FOR ASIA AND THE PACIFIC, BANGKOK

Published by the
UNESCO Principal Regional Office for Asia and the Pacific
P.O. Box 967, Prakanong Post Office
Bangkok 10110, Thailand

Printed in Thailand

The designations employed and the presentation of material throughout the publication do not imply the expression of any opinion whatsoever on the part of UNESCO concerning the legal status of any country, territory, city or area or of its authorities, or concerning its frontiers or boundaries.

TABLE OF CONTENTS

INTRODUCTION

The UNESCO PROAP/APEID Regional Workshop for the Development of Science Education at the Secondary Level with Special Reference to Futures Content was held from 29 November to 5 December 1989, in Beijing, People's Republic of China. The Workshop was co-hosted by the National Commission of the People's Republic of China for UNESCO and the Professional Technical Training Centre (PTTC), Beijing. This activity was a component of UNESCO's 1988-1989 Programme and the Programme of the UNDP assisted project on the Improvement of Science and Technology Education (RAS/86/051).

Participants/Resource Persons

Fifteen participants/observers and resource persons from eight countries attended the Workshop (vide Annex 1 - List of Participants). UNESCO was represented by Dr. F.C. Vohra, CTA, UNDP/UNESCO Science Education Project, Nepal, and Ratnaike, J., Specialist in Science and Technology Education, ACEID, UNESCO/PROAP, Bangkok.

Inauguration

The Workshop was inaugurated by Mr. Jia Xueqian, Deputy Secretary General, Chinese National Commission for UNESCO.

Mr. Lu Yu-Cheng, Deputy Mayor of the Beijing Municipal Government and Mr. Shi Shao-Qi, Chaoyang District Government stressed the importance of the Workshop theme and provided greetings to the participants. A statement about the purposes of and the expectation from the Workshop was made by the UNESCO PROAP/ACEID representative.

Office Bearers

The following were selected unanimously as Office Bearers of the Workshop:

Chairperson	:	Prof. Li Chun (P.R. China)
Vice-Chairperson	:	Dr. Chaleo Manilerd (Thailand)

Future content

Rapporteur	:	Dr. T. Freeman (Australia)
Ratnaike, J.	:	UNESCO PROAP/ACEID acted as Secretary to the Workshop.

The Agenda

The following Agenda acted as a guiding framework for the deliberations at the Workshop:

1. Opening Ceremony
2. Election of Office Bearers/Discussion of Schedule of Work
3. Exchange of Country Comments
4. Future science content areas at secondary level/importance/ content analysis
5. Recommendations for action in regard to sources, learning/ teaching methodologies; learning/teaching experiments/activities, materials
6. Consideration of Draft Final Report
7. Closing Ceremony

Workshop Activities

The Workshop Schedule reflected the following three major components of the Workshop deliberations:

1. country experiences in regard to new trends in science and technology education at secondary level, future content and curricular designs in science and technology education at secondary level, and current status of the development work in this regard;
2. future content, its justification and its analysis;
3. potential sources for reference and consultation, possible learning/teaching activities, investigations and experiments for the secondary level in regard to this content, and likely implementation difficulties.

The country experiences were presented and discussed in plenary. In particular, country experiences dealt with current work in regard to science and technology education after the Year 2000; and the curriculum models, structures, and strategies envisaged for the purpose.

The other two components were discussed both in plenary and in two groups, the Physical Science Group; and the Biological Science Group. Potential content from different significant issues in science and technology of the future, such as new frontiers of science; global issues related to science and technology; and science issues derived from technological advancement, were taken up for discussion.

The discussions on the identification and analysis of content and its justification were triggered by the following four brief presentations looking into the above issues:

1. The Use of Computers and Calculators in preparing for a Career in Engineering or the Physical Sciences by Dr. T. Freeman (Australia)
2. Laser as High Tech for Development: A Case Study from Thailand by Dr. Chaleo Manilerd (Thailand)
3. Biology-based Technology by Dr. F.C. Vohra, CTA, UNESCO/UNDP Science Education Project, Nepal

Similar brief presentations by:

1. The P.R. China delegation, on New Trends and Implementation Difficulties;
2. Dr. Wongchan Wongkaew (Thailand), on possible experimental work on bio-technology; and
3. Dr. T. Freeman (Australia), on possible experimental activities in computer/physics, stimulated discussions on potential directions for the conversion of future content into learning/teaching episodes.

During Group Work, the participants considered further details of the content analysis, the justifications, the experimental work for learning and teaching, and potential resources for reference and consultation.

Interactions with Secondary Education

The Workshop schedule included visits to secondary schools in Beijing, in particular vocational schools, which were incorporating future requirements for socio-economic development in China in their training programmes for students. Indeed, participants had intimate and practical interactions with these training programmes in that the entire service operation at the Workshop, from hotel and food service to the AV and duplication services, were entirely, and highly competently, provided by upper teenage secondary vocational students. This underlined a very real, highly admirable and deeply appreciated dimension about futures in secondary education.

Closing

Prior to the Closing Session on 5 December, the Workshop considered recommendations for further action at national and regional levels, and at the Closing Session, adopted the Draft Final Report of the Workshop.

The Closing Ceremony was conducted by the Chairman, Dr. Li Chun.

Participants, resource persons and observers, and the UNESCO staff, were unanimous in their deep appreciation of the excellent services, generous hospitality and warm personal care and concern provided to them throughout the Workshop by the Organizers. The rich and varied experiences enjoyed by those who attended the Workshop were both unique and rewarding.

The participants, resource persons and observers expressed appreciation of the opportunities provided by UNESCO to share and investigate together a new area of science and technology education.

Chapter One

COUNTRY COMMENTS

Each participating country provided a document and presentation on the thinking, priorities, strategies, design and content being considered nationally for the future science and technology education at secondary level. Each presentation was followed by intensive discussions and clarifications on the various issues involved, both substantive and feasibility.

The following represents a brief summary of the country experiences, and of significant trends and issues, in the development of future science and technology education at secondary level.

PEOPLE'S REPUBLIC OF CHINA

Science and technology are developing rapidly at the present time. It is necessary to let middle school students do, as early as possible, new and developing subjects that represent the future of science and technology. China is making great efforts in the reform of the educational system, content and methods so that education serves better the socialist modernization.

There are five strategies being experimented for introducing new science and technology: (1) to open up the content in parts of teaching materials with knowledge of new subjects; (2) to offer optional courses on new subjects; (3) to organize extracurricular groups for educational activities; (4) to carry out the new subject education in senior vocational middle schools according to specialities; (5) to let after-class organizations organize students in study and research. The contents include environmental science, genetics, space science, biological engineering, super conduction technology, electronic technology, remote sensing technology and microcomputers. The teaching methods vary according to the content and educational equipment; knowledge introduction, experiments and observations, and scientific research. The municipal and district (county) educational administrations, schools and after-school organizations are responsible for the organizational and administrative work. Promotion methods are exchanging experience and citing the advanced workers.

Future content

With such efforts, the new subject education, in Beijing middle schools, has obtained the following development and achievement in recent years.

Environmental education was started in 1987 in 15 ordinary middle schools. They have given elective courses like Environmental Chemistry and Environmental Physics to the senior middle school pupils and organized some of them to take part in surveying environmental pollution and writing theses. The experts gave great attention to "*Noise Pollution Circumstances of No. 15 Middle School and Propositions for Control*" written by the pupils in the No. 15 Middle School, and "*Survey on Pollution of Liangma River*" and "*Survey, Analysis and Design of the Social Environmental System of Bai Yang Dian*" written by the pupils in the No. 80 Secondary School. Some of vocational schools have established the speciality of environmental control.

In recent years, 176 middle schools have opened computer courses for senior middle school students, with successful results. The students majoring in computer in senior vocational middle schools, could master several computer languages, and they all receive training in programming and software making.

A biological research group of the Middle School attached to Qing Hua University, with the help and instruction of the Biology Department of Beijing University, found out a new breed of fruitfly while researching a new mutant breed of Beijing fruitfly. Eleven schools are equipped with electron microscopes of 200,000 times magnification. Some senior vocational middle schools for horticulture set up special tissue culturing laboratories. Some senior vocational middle schools in the countryside applied knowledge of hereditary breeding to productive practices.

Students from the No. 2 Middle School attached to the Normal University, Ba Yi Middle School and Changxindian Middle School for the children of railway workers and staff, took part in the national youngsters competition in designing the space shuttle load project.

The senior vocational middle school of Haidian district offered the laser photo-composition speciality, and students could operate skillfully the computer for composition, and use the laser printer.

In recent years, the Science and Technology Centre for Youngsters of Chongwen District has been popularizing knowledge of super conduction among middle school students, carrying out low temperature super conduction experiments, and have made a superconductive materials with help of the Physics Research Institute of Academia Sinica. This centre is also spreading laser knowledge among middle school students, doing optical experiments with lasers, and students learn to make microfilms with laser technology. Some senior vocational schools have opened microfilming courses.

The aeroplane model group of the Youngsters Science and Technology Centre of Xuanwu District has recently made a low-altitude micro-aircraft controlled by sensing, in co-operation with the Agriculture University. This micro-aircraft can monitor dynamically crop growing. The electronics group has applied electronics technology to musical instrument making and developed many kinds of new electronic musical instruments.

The radio group of the Children's Palace of Haidian district, has organized 15 middle school students, under the instruction of the engineers from the National Meteorology Satellite Centre and the counseling teachers from the Children's Palace, to develop in two years, a small unit able to receive cloud atlases from the Japanese GMS static satellite and the American NOAA Satellite. This satellite cloud atlas receiver adopted IC phase-lock demodulation technology, and made a breakthrough in smallness and multi-functionality. It's technical specifications, such as receiving sensitivity, has surpassed the present level of domestic products, and some specifications reached the level of international advanced products. The biology group has been carrying out botany tissue breeding experiments under the guidance of the Botany Research Institute of Academia Sinica.

The Municipal Science and Technology Centre for the Young organized 10 middle school students to develop low altitude photographic techniques.

Presently, there are two problems in developing the new subjects in education in Beijing's middle schools: (1) the class hours of present subjects are too many to arrange new subjects; (2) teachers are short of knowledge for new subjects. In order to develop the new subject education, it is necessary to make great adjustments, to subject arrangement and content, and to train teachers. The task is difficult, but these problems can be solved while the education reformation is deepening.

INDONESIA

Various conceptions about the future have been worked out. Some concern the negative side of the future, such as the fear of nuclear disaster, polluted environments, depleted resources and the energy crisis. The world will be full of catastrophe and the ones who survive, will have the enormous task of rebuilding a whole new world almost from the beginning. Some conceptions are concerned with the positive side of the future. In the mental make-up of humans, there are creative faculties such as wisdom and good sense. There will be innovative ideas in developing the new modern world. These conceptions are used to chart out the concept of education, education for awareness and education for mankind. Communication and information systems are developing rapidly and effectively so that if we are not aware we will be left behind by the modern world.

Indonesia and other developing countries have the same problems, that is to breakthrough the low economic growth and to put a foundation for improving the quality of life. This needs a big effort in national development. There are two main problems in the process of development. Firstly, the problem of life environment caused by poverty and by the big population. Secondly, the problem of managing the existing natural resources. The destruction of the life environment is caused by the problems themselves and the science and technology used to overcome the problems. This means that the science and technology knowhow and its applications given to students should be selected in accordance with environmental problem.

The 1988 National Workshop and Seminar on Future Science Curriculum in Jakarta agreed to use the following strategy and framework of thought to develop the Future Science and Technology Education Programme.

The Strategy of the Development of Future Science and Technology in Secondary School Curricula.

The Determination of
Science and Technology Education Goals

↓

Institutional Goals of Science and Technology Education

↓

Curricular Objectives of
Science and Technology Education Programme

↓

Instructional Objectives
of Science and Technology Topics and Sub-topics

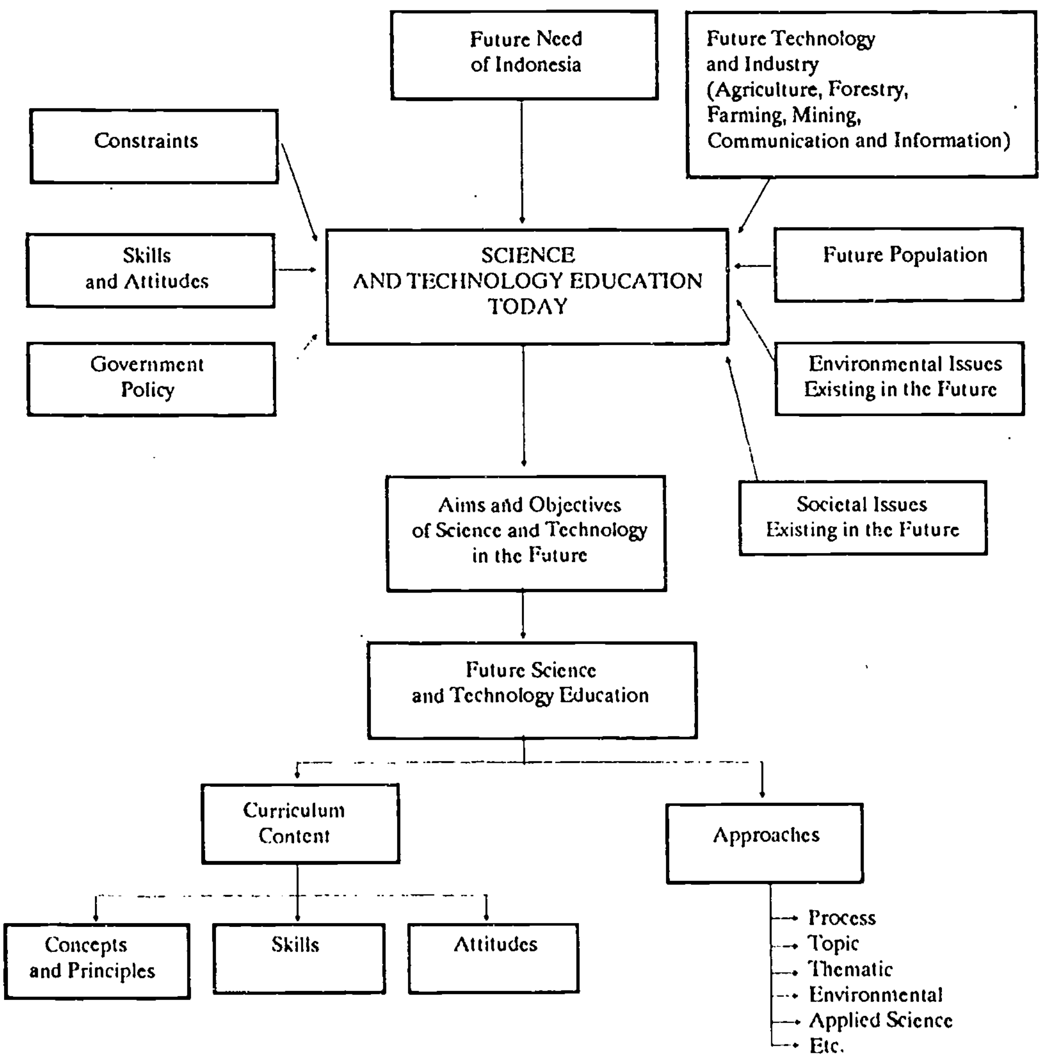
↓

Science and Technology Curriculum Content

The translation of Science and Technology Education Goals into Institutional Goals should be carried out by representatives from research, development and implementation bodies in the Ministry of Education and Culture, various universities, related ministries, related private and public institutions, and related industries.

The movement of institutional Goals into Instructional Objectives is supposed to be carried out by experts in education and psychology, scientists, science educationists, professional leaders in education, supervisors, headmasters and teachers.

The Development of Future Science and Technology Education in Indonesia (A Framework of Thought)



Future content

The Science and Technology Education Programme has the following aims:

1. to provide students with concepts and principles relevant to the implementation and problems of science and technology today and tomorrow;
2. to encourage students to think systematically, constantly and accurately;
3. to provide students with basic skills for entering the world of work;
4. to build unawareness in students of the impact of industry on human life and on the environment;
5. to build a sensitive attitude towards changes in the environment;
6. to encourage students to create new technology;
7. to build students' positive attitudes to preserve and to develop their environment;
8. to build an awareness in students to have two children at the most;
9. to build an awareness in students of the important role of scientists in the building of an improved future for mankind;
10. to explore with students the big ideas of science and technology which have led to man's current understanding of the universe, resulting in far-reaching technological achievements, which figured in civilization's major problems and presented some of the most exciting challenges for the future;
11. to ensure that students learn how to learn, so that solutions to future problems they will be confronted with will not be prevented simply because the relevant information was not learned in school.

Future science and technology areas that are likely to appear in Secondary School Science Curricula among others are: Two children is enough; Biosphere Conservation; Preserve and Develop Our Cultural Environment; The Rapid Growth of Information Technology.

List of Contents of Air and Water Conservation

A. We need air

1. What is air?
2. Do we need pure oxygen?
3. The importance of nitrogen.

4. The importance of carbon dioxide.
5. The greenhouse effect.
6. Photosynthesis and respiration
7. The noble gases
8. Some experiments on air:
   a. Some experiments on photosynthesis
   b. Measure your lung power
   c. Volume of air that passes through your lungs in 24 hours
   d. Does the air you breathe out contain more carbon dioxide
   e. How do clouds form?

B. Pollutants

1. What are pollutants?
2. Smog: the silent killer
3. Photochemical smog
4. Temperature inversion
5. Sulphur dioxide strikes again
6. Acid rain
7. Aerosols and the Ozone layer
8. Lead in petrol: knock anti-knock compound
9. Carbon monoxide: the invisible killer
10. Mercury: the Mad Hatter's complaint
11. Fluorides
12. Cigarette smoke
13. Radioactivity
14. Nuclear power stations
15. Testing of nuclear weapons
16. Storage of radioactive waste
17. Some pollution activities:

Future content

a. How pure is the air you breathe?
b. Collecting dust
c. Looking at smoke
d. What gases are put into the air when coal burns?
e. What gases are put into the air when petroleum products burn?
f. Making and testing sulphur dioxide
g. Does sulphur dioxide affect plants?
h. What do cigarettes deposit in your lungs?

The Boundless Sea

1. Ways of cleaning oil-soaked feathers
2. Pollution and conservation

We Need Water

1. Can you imagine life without running water?
2. Drinking-water from river-water
3. How water is treated in a modern sewage-work
4. The oxygen needs of some animals
5. Study the animal life in a river
6. How much water do you use?
7. Construct a model water-purifier
8. Some chemical experiments on water
9. Questions on water treatment

Water for Agriculture

1. Case history: damming the river
2. Plants and water
3. Some experiments on plants and water
4. Questions on water and agriculture

Water for Washing

1. What is soap? How does it work?
2. Detergents
3. Hard and soft water
4. Soap or detergent: Which is better?
5. Construct a model water-softener
6. Make a bar of soap
7. Experiments on soaps and detergents
    a. Which disperses dirt better - soap or detergent?
    b. Which is better at making oil mix with water - soap or detergent?
    c. Do soap and detergent lather in hard water?
    d. Which are the most alkaline detergents?
    e. Which are better - enzyme detergents or non-enzyme detergents?
    f. Which detergent gives you the most for your money?
    g. What makes algae grow?

MALAYSIA

There are several reasons as to why the Ministry of Education in Malaysia has to review the present curricula of science education. Society today seems to be experiencing a very serious spiritual and moral crisis. Drug abuse, drug trafficking, corruption, misappropriation of funds, personal aggrandizements and hedonism are some examples of the societal problems that Malaysia faces. The Ministry feels that it is time for the educators to devote more efforts into finding ways to minimize these problems. Educating the youngsters with proper moral values for example, may help solve some of these problems.

The education system today is still geared towards equipping students with certificates and occupational skills only. The education system should be restructured to give due emphasis to the overall development of the individual who will later help contribute to the progress of the religion, race and nation. Neither do we consider a student as a total person if he or she is exclusion of other factors contributing to the well-being of young people.

Science education has to be closely linked to technology. Much of the advance in scientific researches aimed at the alleviation of human problems has been due to applications of technology. Technology has a close link with personal, social and economic affairs, and has become a part of the culture of this era of modern living. To cope with the knowledge explosion, it is perhaps pertinent to include in the science curriculum the study of new technology. The objectives in exposing study areas in technology should not only provide students with basic technological literacy and skills, but also aim at helping them develop an awareness of the social consequences of technology. This will gear science education towards increasing students' understanding about the interactive role of science and technology in improving society.

An appropriate science education programme has to be designed to produce the most effective form of training that is sensitive to the changing needs of a country gearing towards industrial progress. The science curriculum should not only be designed to provide the foundation for further education in science and technology, but also to give direct support to vocational and technical training to develop technical skills. This will contribute towards the manpower requirements of a nation progressing towards becoming an industrialized nation.

In the search for new content areas in science education at secondary level in Malaysia, it is necessary for every curriculum planner to review the scenario of scientific and technological advancement in the 21st century. One of the major emphases is to develop in students the ability to acquire intellectual skills and positive values that are required to deal with social problems in everyday life. The inquiry skills, through experimentations and other activities taught in schools, are not sufficient to help students understand the resolution of human issues and problems. The intellectual processes should also be emphasized to develop in students the skills required for analyzing, validating, synthesizing information in making responsible decisions.

The following is a listing of futures science content areas that have been drafted by the Curriculum Development Centre in Malaysia.

1. Science for an Understanding of Nature
2. Science for the Well-being of Man
3. Science for Personal Development

The content is organized thematically and integrates scientific knowledge and its application, scientific skills and sound moral values. Such an approach allows for a wider coverage of several inter-related concepts in a particular theme as well as basic knowledge in science. Four themes are identified for study. These are:

1. Man and the Variety of Living Things around Him
2. The Wealth of the Earth's Resources and their Management
3. Energy for Life
4. Man and the Balance of Nature

For each topic in the syllabus, specifications are provided. These specifications outline the emphases given to each topic and the main content to be covered, including scientific knowledge and applications. Moral values to be inculcated are also defined.

MONGOLIA

The Mongolian People's Revolutionary Party and the Government, having analyzed the present situation and the prospect of developing education, in 1986 worked out the project of "*The Improvement of the School System*" to reflect the scientific and technological achievements of the leading branches of science essential for school education, to develop democracy in schools, to perfect the school network and its development.

The learning of Physics, Chemistry, Biology and Geography has been reformed into a course of natural sciences having taken the logical connection between these subjects and the principle of transferring the curricula from general to special modern scientific and technological progress, development of industrial technology and their prospects. Computers are widely used. So informatics and principles of computing techniques are now taught.

One of the modern key-problems which occurs from scientific and technological progress and human activity, is the question of giving children ecological education. While elaborating curricula, the principles of heritage and reform are the main principles in the curricula of these subjects. In elaboration, curricula are enriched, on the one hand with the rich historical tradition of the people, which always treats nature with great care, love and humanism. and on the other hand, with achievements of modern science in this branch and its ideas. At the same time, excursions and practical classes in laboratories are to be organized widely. The people have a historical tradition of developing cattlebreeding on pasture. The development of this tradition will be continued as it is very economical. On the base of social requirements and traditions, the curriculum for teaching cattle breeding, agriculture and industry has been worked out. In the curriculum, not only problems of tradition, but also of modern mechanized agriculture, and industry are included. Besides special classes were opened for the 6-8th Form, in order to prepare young cattle-breeders. Pupils enter this class on their own or at their parents' request. These pupils learn general education like other pupils. But they do practical work on cattle-breeding. The experiment has shown that the lessons, which were taught by the front-rank cattle-breeders and specialists, were useful. After the 8th Form, pupils may continue their study or became cattle-breeders and may choose one of the following schools: technical-vocational school, or specialized agricultural secondary school. This form of teaching corresponds to the specific character of Mongolia.

Modern science, the technical progress, relation between the society and people, demand the main task of training youth to live in peace without war, to be human and kind. According to this, a special curriculum is available on the following subjects: morality, healthy mode of life, civil rights, economy and ethics. The curriculum includes questions dealing with customs, traditions, mode of life, relation between people and society, economy, state law, civil rights.

According to this programme, pupils of the 1-4th Form must take part in work at home; 5-7 Form pupils in school surroundings, 8-9 Form pupils in the process of the country's production. The teaching staff of the school may change 10-50 per cent of the school hours. It gives an opportunity to realize the whole programme, to support and develop the independent work of teachers, to form the pupils' ability to work, to live. The purpose of the 6-7 subjects for the 1-4 Form pupils is to give them an ability for successful study, knowledge of scientific, morals, ethics, healthy, mode of life and collectivism. There will be 8-12 pupils in the optional classes from 8 Form and they will be taught through a special programme and handbooks. There are several optional classes of the following subjects, mathematics, physics, chemistry, biology, foreign languages. These optional classes for the 8-9 Forms are organized as inter-school classes.

The 10-11 Form pupils will get general education according to modern requirements. From the 10th Form, pupils will be involved in specialized training: mathematics-computer, physics-technology, biology-agriculture, geography-economics, chemistry-technology, language-history, and so on. The specialized subjects will be taught by the special programme. But the other subjects will be chosen by the pupils according to their interests, and these subjects have the ordinary programme. This method of training releases pupils from "*compulsion*", makes them responsible, and gives them more free time for self-development and self-education.

Scientists of the Academy of Science, the teaching staff of institutions, secondary school teachers, famous honoured culture and art workers, are experiencing working together on projects of the new reforms in order to improve inter-lessons and inter-theme contacts.

The curriculum of secondary schools consists of two logically connected parts, core and optional: 30 per cent of all hours of the 1-11th Forms will be devoted to optional courses.

PHILIPPINES

The Philippines is undergoing socio-economic and political changes. Hence, education sees the job of developing the individual so he can participate and live successfully in a challenging, highly competitive, changing, technological world.

It is relevant to the goals of science education in the Philippines. These goals are:

1. to be more responsive to the needs of the Philippine society and to the national government goals;
2. to strength n the scientific knowledge, processes and values acquired in the earlier grades for scientific literacy and the improvement of the quality of life;
3. to communicate the wonders of scientific endeavours and stimulate students with aptitude in scientific and allied careers for the development of high level scientific manpower of the country.

The Science Education in the Philippines twenty years from now is envisioned as enriched Science and Technology courses of the newly implemented New Secondary Education Curriculum. The following is a listing of the future science content in designated year levels:

Future content

Science and Technology I

i. Introduction to Science and Technology I
ii. Forces
iii. Forms and Transformation of Energy
iv. Naturally occurring changes
v. Living things and their environment
vi. Forms of Life
vii. The Earth and the Universe

Science and Technology I is exploratory in nature. It presents basic concepts in physics, biology, chemistry, earth and space science.

Science and Technology II

i. Introduction to Science and Technology II
ii. Changes on Life on Earth
iii. Chemical and Cellular Basis of Life
iv. Life Energy
v. Genetics
vi. Basic Concepts in Genetic Engineering
vii. Reproductive Processes
viii. The Organ Systems
ix. Basic Concepts in Biotechnology

Science and Technology II course is biology based. It studies natural phenomena in living things as it aims to develop understanding of man's living world and his interaction and relationship with the environment. It presents biological problems related to conservation, food production, health, reproduction and heredity.

Science and Technology III

i. Introduction to Science and Technology III
ii. Changes in matter
iii. Molecules

iv. The atom

v. Periodicity

vi. Chemical Bonds

vii. Change, Energy and Time

viii. Solutions

ix. Acids and Bases

x. Carbon and Its Compounds

xi. The Molecules of Life

xii. Colloids

The core of Science and Technology III is chemistry aimed at stimulating and preparing students for a career in the sciences. It presents an overview of chemistry in terms of atomic/molecular nature of substances. It is geared towards the acquisition of an essential foundation of a student's development into a productive citizen. It considers chemical knowledge applied in technology, which has immensely influenced man's lifestyle.

Science and Technology IV

i. Introduction to Science and Technology IV

ii. Force and Motion

iii. Gravity and Satellites

iv. Electromagnetic Theory

v. Electromagnets

vi. Electronics

vii. Waves

viii. Matter and Energy

The core of Science and Technology IV is physics. It is treated as a product of experiment and theory. It aims at developing concepts as basis for the interpretation and understanding of physics phenomena. Through a historical development of concepts, physics technology is presented, and its humanistic background shown.

The incorporation/integration of concepts of the above-mentioned topics in the proposed science curricula of the secondary schools is a need. Recognition and comprehension of updated concepts will make the student:

Future content

(1) conscious of the pace of technology advancement and scientific breakthrough; (2) an expert in scientific and technological investigations; (3) able to adapt, utilize and improve existing technologies.

These modern day concepts in Science and Technology will also encourage technology sharing and transfer. In totality, inclusion of these topics will contribute to national productivity and improve the quality of life of the Filipino people.

THAILAND

The Thai Education System provides for six years of primary education, three years of lower secondary education, three years of upper secondary education or three years of vocational upper secondary education, and four years of tertiary education. Primary education is compulsory for all children from the age of 6 - 12. Preparations are being made to extend compulsory education to include lower secondary education.

The Ministry of Education is responsible for the provision of primary and secondary education, with the Ministry of University Affairs responsible for tertiary education. There are some exceptions in that the Ministry of Education maintains some teachers colleges and technical colleges which grant bachelor degrees in various subjects. Also private agencies are allowed to run private schools and universities under terms and conditions provided by the Ministry of Education and the Ministry of University Affairs.

The Department of Education Techniques of the Ministry of Education is in charge of curriculum development for primary and secondary schools in all subjects, except in science and mathematics. As early as 1972, the Government of Thailand established a semi-autonomous body in the form of a state enterprise tasked with the promotion of the teaching and learning of science. That organization is the Institute for the Promotion of Teaching Science and Technology (IPST). The IPST at present has a regular staff of about 200 persons and draws support from part-time staff joining on a secondment basis. As a state enterprise, the IPST is held accountable to its Governing Board whose membership consists of Directors General of various departments of the Ministry of Education as ex-officio members and also distinguished academics. In this way, the IPST maintains close links with the Ministry of Education and its schools and also organizations and institutes involved in the advancement of science and technology in Thailand.

Since 1972, the IPST has engaged itself in the improvement of the teaching and learning of science, technology and mathematics as an on-going activity. In the beginning stage, all textbooks in science and secondary school level and mathematics at the primary and secondary school levels were upgraded and rewritten. Science equipment and apparatus and teaching media needed for teaching new curricula were produced on a large scale and made available to all schools. Teachers were also trained to teach the new curricula. As of now, there are science and mathematics courses that are obligatory for all children upto the last year of the lower secondary schools. In the upper secondary schools, there are science courses which are obligatory for children who will take up science or science-related careers at the university level and also science courses obligatory for children who will study social science, humanities or such similar subjects at the university level and for those who will seek employment at the end of their secondary school years.

The time ratio between the obligatory and elective courses is about 80 to 20 per cent.

The salient features of the science and mathematics curriculum developed at the IPST include the following:

- emphases given to practical work using low-cost equipment;
- development of pertinent science concepts followed by applications;
- topics especially in science for non-science students related to students' daily life;
- inquiry methods introduced wherever possible;
- inculcation of values and attitudes that science and technology can be used to solve problems at individual and social levels;
- care for life and the environment.

As a result of the plan of the Department of Educational Techniques to reform the national curricula beginning from 1990, science and mathematics curricula for lower and secondary schools will also undergo changes. In the new curriculum system, more elective subjects will be made available for children, both at primary and secondary school levels. Elective courses are to allow teachers and local education authorities more participation in the design of curricula, and permit children to choose what to learn according to their aptitude, abilities and interest.

Future content

As the manpower needs in Thailand in the fields of science and technology, especially in the area of material science, computer, electronic, and bio-engineering, will be very acute during the next decade, the science and mathematics curricula from the primary to upper secondary school will be influenced greatly by that need. It is therefore to be expected that new subjects related to hitech, such as laser, superconductivity, materials science, biotechnology will be introduced, hopefully in imaginative ways, to children in the upper secondary schools. New emphases will also be expected to focus on content for talented children, while science and mathematics for non-science children will be more related to applications and what children experience in their daily lives. Inquiry and scientific method will continue to receive attention, especially at the primary and lower secondary education. After that, children will be expected to apply science method and inquiry approach in a natural manner familiar to them in their early years of education.

SOCIALIST REPUBLIC OF VIET NAM

The Vietnamese education system has completed the change from the 5-3-2 to the 9-3 system, with the new education system. Compulsory education begins from the age of 6 and continues until 15. In the Vietnamese education system, the schools which provide the first nine years of the first stage of compulsory education are known as basic schools. At the end of the nine basic school years, children who pass the screening examination with good marks (about 30 per cent of the total child population), go on to the second stage school (Grades 10, 11 and 12). All students of the second stage school at the end of Grade 12 take the Exit Examination organized on a nationwide basis.

Students who satisfy the minimum grade requirement may apply to sit for the entrance examinations organized by universities and colleges. Generally speaking, only 6 to 8 per cent of the graduates of Grade 12 are admitted to higher education. Those who fail to find places in tertiary education may either receive further training at job-training centres or attend secondary vocational schools. This explains why, in the past, second-stage schools tended to organize their curriculum on the subjects that prepare students for future employment. It takes many years of experience and discussion to realize that the situation is not appropriate to Vietnamese educational development. The general education in the second stage school should give more attention to fundamental knowledge and traditional science subjects such as physics, chemistry, biology and mathematics. In facing the challenge at the close of the twentieth century, and preparing to meet the twenty-first century, Vietnamese educators see clearly that innovations in the organization of teaching/learning processes, in methodology and in the subject contents are urgent matters.

For Viet Nam, five areas of science and technology development are regarded as priority:

- Computer science (hardware and software)
- Automation in production and processing, and micro-electronics
- Bio-technology
- New Materials Science
- New types of energy (renewable as well as non-renewable)

It is expected that in the near future, students will face development problems in the above indicated areas, and this is why they should be prepared.

Trends and Issues Raised by Participating Countries

The country presentations and their follow-up discussions clearly demonstrated the common concern with the importance of well planned future content. The major motivation for such planning came from rapidly developing socio-economic trends, due to the urgent need in all countries for technological development. Participants were aware of the accelerated and continuing growth of science and technology. It was agreed that the need for secondary school learners to be aware of these developments in a fast changing world scene was a challenge best met by science education. Agreement was quickly reached among the participants, when defining new areas of possible futures content. Generally speaking, the content areas to be included are: bio-technology, environmental concerns, health information, electronics, renewable energy sources, with lasers and high temperature superconductivity. Another issue canvassed and supported was the general question of moral and ethical values in relation to science and technology.

Several detailed analyses of bio-technology were presented and these made it clear that this field has become an interdisciplinary subject in itself. As with the other items, the problems of definition and categorizing the subject cannot remove the urgent demands that bio-technology be explained in science classes at all levels. Similarly, environmental concerns raise broad multi-disciplinary issues, but it appears that these issues have started to filter through science syllabuses and some experience in teaching these items has been gained. In particular, practical environmental problems have enabled many students to gain an appreciation of how science can help them protect the familiar surroundings. Health information needs clearer paradigms, but it is likely that this topic will also be readily appreciated by students at all levels. Micro-electronics, lasers, materials science, superconductivity are among the new growth frontiers of science and technology knowledge and cannot be left out of a future curriculum content. It is possible that moral and ethical questions can also enrich the context of many areas of new science and technology content.

Many new content items still require a greater depth of content analysis. This is exemplified by the various aspects of electronics, again a subject in itself, and one that is rapidly updating its content. Renewable energy resources and efficient conservation practices have become more familiar environmental issues, but as components of physical or biological sciences, they also suffer from rapidly changing trends and technological methods. Lasers, superconductors and new materials will probably retain their relevance as they become increasingly used in many technological applications. As these items are available for classroom use, it is unlikely that future secondary school programmes will be able to avoid their application. It is understood however that other discoveries may demand urgent consideration and as a consequence some of the above items could become displaced.

While the general topics such as those mentioned, have been considered, more thorough and comprehensive analyses that cover the many parameters involved, including those of ethics and values as well as prerequisite knowledge bases required for the learning of the new content areas, are still required. The present level of resolution is limited by the interdisciplinary nature of many of the new content topics as well as by different national needs. Preliminary attempts at content analysis have highlighted the need to involve a variety of resource persons from different disciplines and occupations, including those from technology.

There is a problem with the introduction of new science and technology content. If it is added on to enrich existing content, steps must be taken to prevent the accretion of too much syllabus material specially at purely factual level (the "*barnacle*" effect). Indeed the addition of new science and technology items could well demand the retention and probable extension in depth of relevant items already in the current content, to act as prerequisite foundational bases for the new content. Optional and core course structures have been used in some countries to resolve this conflict. The prescribed time allocation between core material and options varies with different countries and with different categories of students within these countries. In countries where external final examinations are taken, the options cause some concern and suspicion. Where decentralized or school based assessment is practical, it is usually easier to meet local requirements using the core-option system.

Optional learning, in some countries, has been extended to out-of-school science and technology activities, which in several countries, have blossomed into highly creative and complex hands-on productions by students. The out-of-school modality appears to be most effective for blending science and technology in the development of an imaginative product, in the mobilization of high level human and other resources for learning and in providing considerable incentive, development of self esteem and encouragement to students to study science and technology further, especially at tertiary level. The out-of-school modality can encourage the use of process skills in science, such as problem solving, critical thinking and constructive synthesis in uncontrived situations and make them integral parts of the learning performance of students.

A second, as yet unresolved, issue arises from the extent to which technology needs to be described, as compared to the explanation of the scientific theories that undergird it. This issue becomes a very serious matter, since external sources such as the "*mass media*" are already referring to many spectacular technologies and break-throughs, and frequently with an aura of "*magic*". An adequate general education of students at the secondary level is required so that they can make choices with understanding, concerning these matters, particularly with ethics and values colourations. In addition, a vigorous approach is required to prepare the intellectual stream of a nation for tertiary studies in science and technology. Some countries are able to select and encourage talented students by the use of national and/or international Olympiads in the various science, technology and mathematics areas. Where such special attention is given to able students, a flexible opportunity remains for the exploration of in-depth coverage of topics from technology and science, without ultimately disadvantaging the other students.

Throughout all the above considerations, the competence of secondary school teachers to undertake the tasks involved remains a matter of deep concern, a third major issue. Some forms of in-service enrichment of teachers are available in many countries, while teachers from higher levels of education have been mobilized to assist with teaching new areas. Suitable strategies and implementation plans for this problem seem, at best, to be still at the formative stage, in most countries in the region. This situation will remain until the future science with technology curricula are more clearly defined, and resource networks become available to teachers to practice their learning to learn competencies.

Most of the successful examples of the introduction of components of new science and technology content, appear to come from affluent urban areas. This is not surprising, since these particular areas are also affluent in teaching and knowledge resources. This observation points to the fact that while new innovations can be tested in affluent environments, they will not necessarily spread nationwide no matter how successful they prove to be in the affluent areas. In the longer term, consideration must be given to the general provision of adequate quality support items, especially to disadvantaged areas, together with the implementation of any new science syllabus in the future.

Chapter Two

FUTURE CONTENT

Having discussed the importance of the several new content areas for future science learning at secondary level, the Workshop undertook the task of attempting to indicate the kinds of content analyses countries would need to undertake, prior to entering the complex tasks of curriculum development. The importance of the selected new areas was also indicated. Use was made of the substantive papers and presentations of the resource persons.

Experience gained from previous reforms in science education, since particularly the 1960s, shows that (a) content analysis is an essential prerequisite exercise for systematic curriculum development; and (b) it consists of several operations, not necessarily sequential. Content analysis may start with content specialists providing a comprehensive list of knowledge elements (factual and conceptual) ordered in terms of the most significant conceptual structures of the subject. Curriculum developers would then select the content sub-set appropriate to a given learner population. This mode proved to be most productive during the reforms of the 1960s, especially for updating content in terms of concepts and for removing historical content debris non-essential to focused concept formation in the subject area. Another mode used has been the discursive description of a content area which would indicate the scope of the content within selected boundaries, to be followed later by a detailed content analysis in the manner of the first mode.

The analyses undertaken by the Biological Science Working Group and the Physical Science Working Group are not prescriptive, either in mode or details, but explorative, and merely attempt to indicate some examples of types of steps in content analysis that may be undertaken. Even then, the few examples chosen are not comprehensive within themselves, but provide possible stimulations for further content discussions in the countries on these examples as well.

It should be *stressed* that the Working Groups only attempted the very *first step* in content analysis, a first approximation to a "*scope map*", which also embodies the justifications for including the content. The total process of content analysis itself would involve many more steps before the intended learning outcomes, even in the cognitive domain, are identified concretely and tied to their respective conceptual structures, in preparation for developing learning sequences.

Future content

The two Groups attempted different techniques for this first step analysis, and used different extents of detail and format in the analysis. Because of the acknowledged current importance of Bio-technology, this area of learning was provided specially detailed consideration by the Biological Science Working Group. It is an example of the initiation of content analysis, of a growing edge of science today. The content analysis also places the new content items in a historical perspective, to emphasize that even if the "*present*" content is "*radically new*", it has its own co-ordinates and roots in the stream of time and knowledge development. This analysis merely illustrates, as an example, the kind of first analysis that may be needed in other new content areas as well.

The Physical Science Group, on the other hand, focusing on Physics, considered the need for a core of foundational "*traditional*" basic science content on which to build the new science. The new science may be placed in optional and post foundational positions in the curriculum specifications. A scope map was also developed for the area, Laser.

New content cannot be merely attached to an existing curriculum. Aside from subject matter logic, curriculum overload has also to be considered. Adequate learning time has to be provided for the learning of new content, which frequently is complex, multi-disciplinary and requires other prerequisite content for the learning, especially if the learning is to be more than at the level of factual recall.

Taken together, the deliberations of the two Working Groups represent some of the important content analysis parameters, even at its first stages, that may need to be considered in identifying new science content for future science and technology education at secondary level. The Working Group deliberations also portray two *different* strategies for the possible entry of future content into science education curricula.

Since science and technology are expanding at an unprecedented acceleration, it is highly likely that the corresponding content will also keep on changing with equal rapidity. Hence, the process of frequent and fast updating of content would need to be built into the content analysis activities as a "*routine*" continuous action. Aside from the specification of intended learning outcomes having to deal with very new, and often complex and interdisciplinary or multi-disciplinary content, the rapid rate of change would be an additional complication, even at this first step in curriculum development. Rate of change in curriculum development would need to match the rate of change in future science content, an aspect of curriculum design that has hardly been considered by most countries of the region. The development of the "*scope map*" may well help in this direction.

A major achievement of the work of the Groups was the surfacing of options for content analysis, and for the introduction of the new content into current curricula. With the significant complication of multi- and trans-disciplinary content of the new areas, the usual subject-matter content analysis of the 1960s does not necessarily apply. A major breakthrough at the Workshop was the use of the technique of the "*scope map*" or a first contour of the new content area. Undoubtedly, a "*purely*" subject matter content analysis into the various content elements that form the new areas, structured according to the appropriate conceptual schemes, *is* possible, but it would be a long and possibly contentious task, in the context of the multi- and trans-disciplinarity of the content. The "*scope map*" or contour format, however, makes it possible for a practitioner in the area of the new content (the equivalent to the content expert of the 1960s), to come up with a relatively quick description of the "*borders*" of the new content area for the purposes intended (for example, secondary education); which may then be followed by a further delving into the "*map*" to identify specific detailed content elements; and which itself may be followed with appropriate schematic and conceptual structuring, accepting that since the multi- and trans-disciplinary nature of the content is a reality, there may well be several "*helixes*" of conceptual structures inter-connected and interacting with each other (like a more complex model of the DNA type), rather than the "*simplistic*" linear scheme of content analysis, in the individual subject areas, of the reforms of the 1960s.

Deliberations of the Biological Science Working Group

The "*large new areas*" of content in the biological sciences were identified as follows:

- Human biology, health and nutrition
- Social biology and sanitation
- Human and environmental ecology (Populations and family planning, etc.)
- Marine Sciences (oceanography)
- Natural resource management involving their wise and rational use
- Bio-technology

Future content

Human Biology, Health and Nutrition

- Human body systems
- Physiology of these systems
- General hygiene, nutrition and health
- Common ailments in the region and their prevention

Marine Sciences

- Marine environment
- Marine organisms - use and ecology
- Impact of human activities on marine environment
- Conservation and use of marine resources
- Nutrient cycles
- Ocean currents
- Movements of fishes, nutrients and pollutants
- Sea shore ecology with special reference to mangroves

Natural Resource Management Involving Their Wise and Rational Use

- renewable resources, the rate of utilization and the rate of replenishment
- distribution of resources
- community role in conserving natural resources
- efficiency in harnessing solar energy
- biomass production
- efficient use
- air, water management
- global environmental issues
- what constitutes wise and rational use of natural resources
- forest repletion and replanting

Social Biology and Human Ecology

- family life and control
- community health and sanitation
- human populations and their behaviour - interaction with environmental factors and resources
- human behaviour and stress
- human sexuality - its role under bio-technology
- agricultural systems

Bio-Technology

[This is provided detailed analysis below].

Bio-technology - A Scope Map

In basic practice, bio-technology is nôt a new subject. It has its origins rooted in antiquity dating back to the early history of human beings. Its substance relates to some very ancient human activities using techniques based on biological processes. As such, food gathering, preparation and preservation have been essential components of the culture and economy of early communities around the world. The Neolithic Era (9000 BC) marks the transition from hunting and food gathering, to food production, involving cultivation of edible plants - wheat, barley, millet, rye, and malting technology.

Starting perhaps from an unexpected discovery of fermentation, human beings have been trying to improve their bio-craftsmanship for exploiting different raw materials through the use of living organisms or their biological processes. Thus, the brewing industry has been known 3500 BC; and making of wine, bread, cheese, yoghurt etc. has been a common heritage in many cultures. Although ignorant of the natural principles involved, farmers have long practised the art of improving their crops through careful selection of seeds from desirable plants. Similarly, they have also succeeded in developing better breeds of domestic animals long before the researches of Mendel. It has been common knowledge that, working with phenotypes, animal and plant breeders have been able to produce chickens that lay more eggs, cows that give more milk.

Following the discovery of Watson and Crick, much is known about how the genetic code of cells is duplicated and distributed to offspring cells.

Future content

Recent researches in the field have also given scientists the ability to isolate genes from cells, duplicate them in a culture, and introduce them into other cells to achieve various results. These techniques, collectively referred to as "*genetic manipulation*", are significant in their potential to overcome some of the natural restrictions limiting the biological variability range under conventional breeding methods. These newer techniques enable scientists not only to develop organisms containing genetic information from diverse sources, but also to hasten the achievement of certain breeding objectives.

The "*bio-technological revolution*" is, tacitly, the re-evaluation and refinement of old knowledge and traditional practices in the light of better understanding of various biological processes, emerging new information about the genetic makeup of cells, technological possibilities, and their subsequent industrial applications. The earliest techniques of fermentation originated as homecrafts and were partly responsible for the change from cottage industries to town-based crafts. Traditional bio-technologies in this field in early history involved natural processes. Later the process was based on mixed cultures by wild yeasts, bacteria, fungi, etc., followed by batch inoculation with selected micro-organisms and control of enzymatic reactions. It is only recently, through the use of genetic technology, that the process has become more efficient and continuous, thus acquiring high industrial capabilities.

Bio-technology as a distinct discipline of study and scientific research has emerged, perhaps, only in the early 1970s. Since its emergence, it has made tremendous strides, making an ever-increasing impact on human life, with important implications and applications in industry and commercial enterprises covering agrofood, fertilizers, fuels, fibres, chemicals and pharmaceuticals, as well as crop disease and pest control. Though still in its infancy, it has already demonstrated its fruitful potential not only in intellectual endeavour, but also in practical terms.

The most significant factor behind this upsurge seems to be the rapid progress made in the field of molecular biology, genetics and gene technologies. Studies of nuclei of individual cells led to the discovery of chromosomes and their behaviour, and subsequently to the double helix of DNA, the carrier of instructions or code for the development of a future organism. As a result of a continuing series of breakthroughs in the understanding of DNA during the last few decades, it is now possible to manipulate the genetic codes of micro-organisms. With the discovery of restriction enzymes in the 1970s, use of gene manipulation has resulted in the production of useful and valuable biological products such as bio-insecticides, vaccines, human insulin, human somatostatin, human growth hormone, interferons, and antibodies. The use of Restriction Fragment

Length Polymorphism (RFLPs) can help to detect the presence of genetic disorders such as Huntington disease, cystic fibrosis, sickle cell anaemia, muscular dystrophy, thalassemia and haemophilia.

Further, developments in gene technology have enabled the identification in the human karyotype of approximately 50 fragile sites and 20 oncogenes that may be involved in human malignancies.

Likewise, it is also possible to use micro-organisms as vectors to induce new genetic messages into animals and plants with a view to altering their characteristics and improving their breeds. For example, viral vectors can be used to induce the gene for a missing enzyme into target cells as a possible measure for correcting metabolic disorders. Similarly, the use of recombinant interleukin-2 can help in the treatment of cancer. Genetic manipulation techniques can also be used to improve crop yield, nutritional quality of seed crops, and the resistance of crop plants to pests, pathogens and environmental changes, as well as to increase milk and meat production by animals. These successes have encouraged the industrial use of bacteria, yeasts, filamentous fungi, plant and animal cells as well as enzymes, to produce commercially a wide variety of products.

Genetically engineered microbes now form the basis of many revolutionary processes which are helping to reinvigorage, diversity and change the character of traditional land-based, biologically-based, and health-related industries, with subsequent impact on agricultural practices, medical research, waste management and pollution control. The literature is full of examples of industrial activities where bio-technologies have either already replace, or are in the process of replacing, the traditional patterns of technologies. Such cases include the manufacture of textile products, synthesis of flavourings and seasonings, production of ethanol, biogas and hydrogen, and extraction of metallic elements. Bio-technology methods are already increasingly used in the mass production of yeasts, algae, and bacteria with a view to provide proteins, amino-acids, vitamins and scores of other useful products more economically. In particular, its use in the development of new and improved crop varieties is advancing rapidly worldwide, and is an area which even the developing countries with an agricultural base cannot afford to ignore. Genetic engineering also holds a great promise to improve the techniques for diagnosing and treating hereditary diseases, cancer detection and cure, treatment of waste water and in solving problems of hunger, health, nutrition, sanitation and energy. Prospects for its use to enhance mineral and oil recovery as well as the production of energy from the world biomass, are equally strong. The recent experimentation with gene manipulation and cell fusion technology have further opened up many new possibilities within industry, of new products, improved processes, increased production, reduced costs, and reduced pollution and wastage.

In view of its universal applicability and usefulness in everyday life of people, biotechnology is now recognized as a potent tool in the future development of both rural and urban economies in the developed as well as the developing countries. As such, many nations including Australia, Great Britain, Canada, France, West Germany, Japan, USA, and O.E.C.D. are pushing it both politically and financially and have prepared plans for encouraging its use in industry and to improve the quality of life of their respective populations. One of the reports from the Office of Technology Assessment in the USA claims that more than 100 compounds, representing 17 different product categories, ranging from amino-acids to viral antigens, have a current market value in excess of 27 billion dollars. Recent researches and techniques of genetic technology have contributed and will continue to do so greatly, to enhance knowledge in biological sciences. Some of the techniques developed as part of the DNA technology have already helped to improve understanding of the regulation of the genetic mechanisms, development and differentiation of organisms, the organization of the genome, the nature of the immune response, X-chromosome inactivation, human evolution, sex determination and even the relatedness of species.

While contributing to solve many problems, the practice of bio-technology can create new ones of unknown dimensions. Inherent in this field are both benefits and risks which potentially can alter not only the environment, but also humans. The growth of bio-technology in recent years has been so fast and dramatic, that the general public's understanding of what bio-technology means, and its appreciation of the influence of research outcomes in the field on daily life, has failed to keep pace with progress. Even many scientists seem to have no time to pause and assess the full impact.

The capacity to manipulate the genetic apparatus in both the laboratory and the field has given the human creative powers that threaten to pose new dilemmas and confront critical paradoxes. The more learned about the nature of life, the more are living organisms reduced to malleable structures open to experimentation and change, at the whims and fancies of scientists. Some of the hazards of genetic engineering in relation to plants may include production of more vigorous weeds, change in the niches and pathogenicities of plant viruses and soil bacteria, increase in the breakdown of fertilizers as well as the production of nitrogen oxides (denitrification), decrease in the variability of crops etc. More recently, there has been growing concern that altered microbes may inadvertently tip nature's balance against the human. Questions also involve legal and ethical issues in direct confrontation with traditional value systems. There are many unanswered questions especially in relation to safety, ethics, and long range effects of gene manipulation on evolution, human health, disease and the quality of life in general. Depending upon national development goals, socio-cultural and moral traditions, the answers to such questions will, of course, vary from country to country.

Disciplines and Techniques Contributing to Bio-technology

Although there are many possible ways of grouping the applications of bio-technology, the Biological Science Group classified the applications under five headings: fermentation technology, waste technology, bio-molecular engineering, environmental technology, and renewable technology. The development of these applications is subject to contributions of a number of disciplines such as biochemistry, genetics, molecular biology, microbiology, mathematics, computer technology, engineering and techniques including market research. Of these, microbiology and molecular biology stand out in their importance. The latter has much advanced the understanding of the nature of living systems, in particular with reference to the molecular and genetic bases of life. Today genes are no longer regarded as abstract units without material basis, but rather as discrete molecules performing their functions in special ways. A great deal is known about single genes and their arrangements in cells. Virtually every living organism uses the same genetic code to translate its hereditary information carried in the DNA. This commonality has enabled the molecular biologists not only to slice through DNA in specific locations, but also to isolate this material and recombine it with DNA from another source to form recombinant DNA (rDNA). This technique has found great use in industry and commerce. The structure of the DNA molecule is identical among all living things, from an amoeba to the human, from a blade of grass to a tall tree. Further, it is regarded as the store house of all information needed to perpetuate life or make an organism. By using complicated series of biochemical processes, the information contained in the genes is translated into the actual stuff of which organisms are made. The ability to "*engineer*" various traits by manipulating the DNA i.e., transferring of genetic traits from one organism to another, was demonstrated in the early 1970s.

The monoclonal antibody techniques permit the production of large amounts of specific proteins such as antibodies and interferons for research and chemotherapy. Antibodies have two useful characteristics: first, they are extremely specific i.e., each antibody is produced in response to a specific foreign antigen (normally a protein) in the blood stream; and second, some antibodies, once activated by the occurrence of a disease, continue to provide resistance (immunity) to that disease (e.g. antibodies to chicken-pox and measles). This feature of antibodies enables the development of vaccines. Because of their specificity, monoclonal antibodies can be used not only as protection against disease, but also to diagnose a wide variety of illnesses. They can also help to detect the presence of drugs, viral and bacterial products and other unusual or abnormal substances in the blood. The technology underlying their production involves the fusion of antibody-producing cells from the spleen of a mouse (previously immunized with a particular antigen) with mouse cancer cells. These hybrid spleen-cancer cells are called hybridomas and can be grown in culture. They express both the spleen cell's ability to recruit specific antibodies, and the cancer cell's ability to proliferate continuously. Since each spleen cell produces only one antibody protein, the monoclonal antibody so produced corresponds with just one specific antigen.

The modern bio-process technology is an extension of ancient bio-techniques for developing useful products through natural biological activities e.g., combination of yeast cells and nutrients forms a fermentation system in which the organisms consume the nutrients to produce alcohol and carbon dioxide as the end products. Use of living organisms in this technology has many advantages over conventional chemical methods of production: they usually require lower temperatures, and pressures; they can use renewable resources as raw materials, and greater quantities can be produced with less energy consumption.

Various other themes for the basic understanding of biotechnology include: microbes and their products; cell manipulation and culture; fermentation; enzymes and enzyme technology.

Bio-technology, like any technology, aims at developing either an absolutely new produce (or a process) or making an existing product more efficiently and at less cost, through a series of logical steps from initial ideas through process and market investigation. From the view point of the profitability of an industry, the question of market research involving identification of market requirements is very significant. This can help in designing a new product that will fit the market needs and fancies.

The main bio-technology themes may be divided into two groups, one based on the utilization of the natural processes of living organisms or cell components (Figure 1) and the other relating to utilization of living organisms modified by gene technology (Figure 2).

Figure 1. **Possible bio-technology themes dealing with the utilization of natural processes in living organisms or organelles and the general biology topics, in which they can be covered (in higher grades of secondary education) — Bayzhuber, H(1989) (UNESCO)**

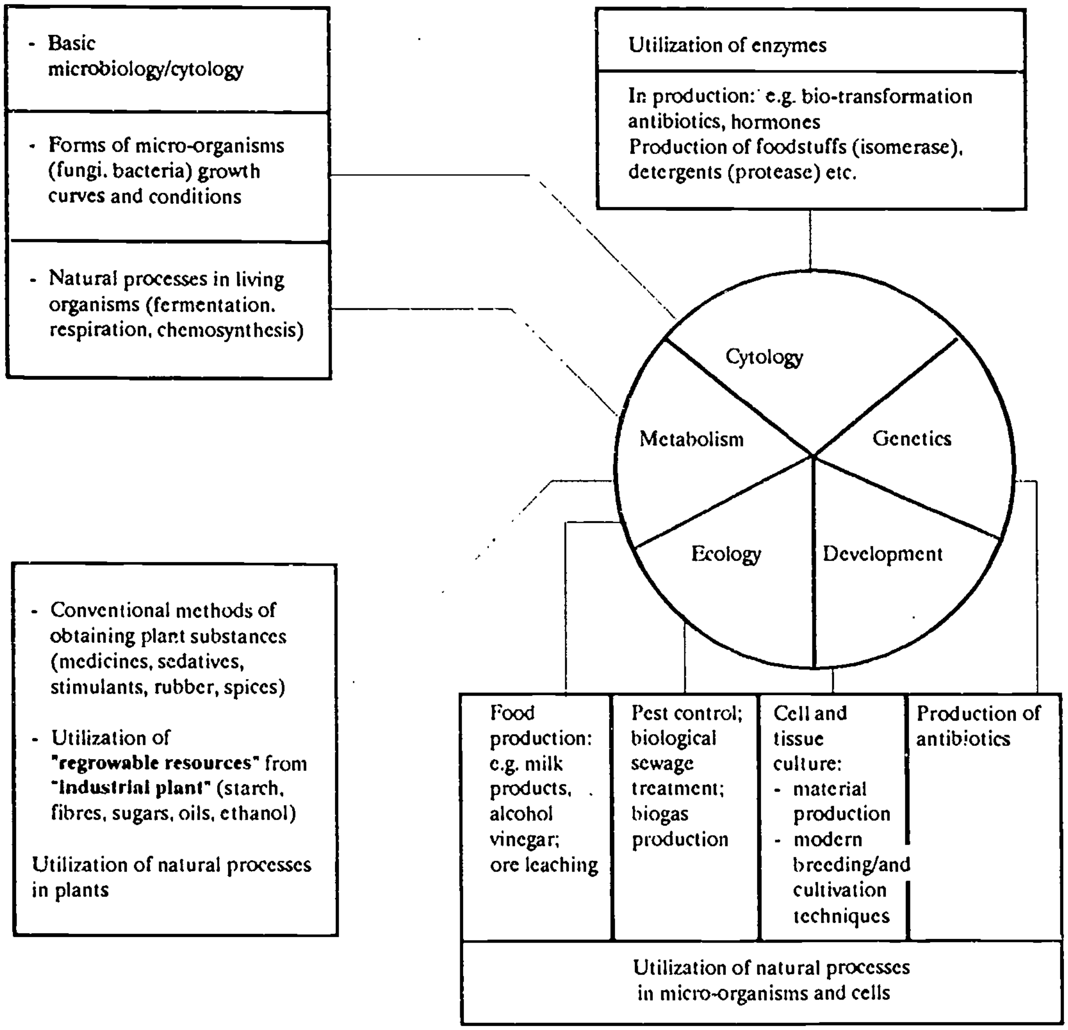
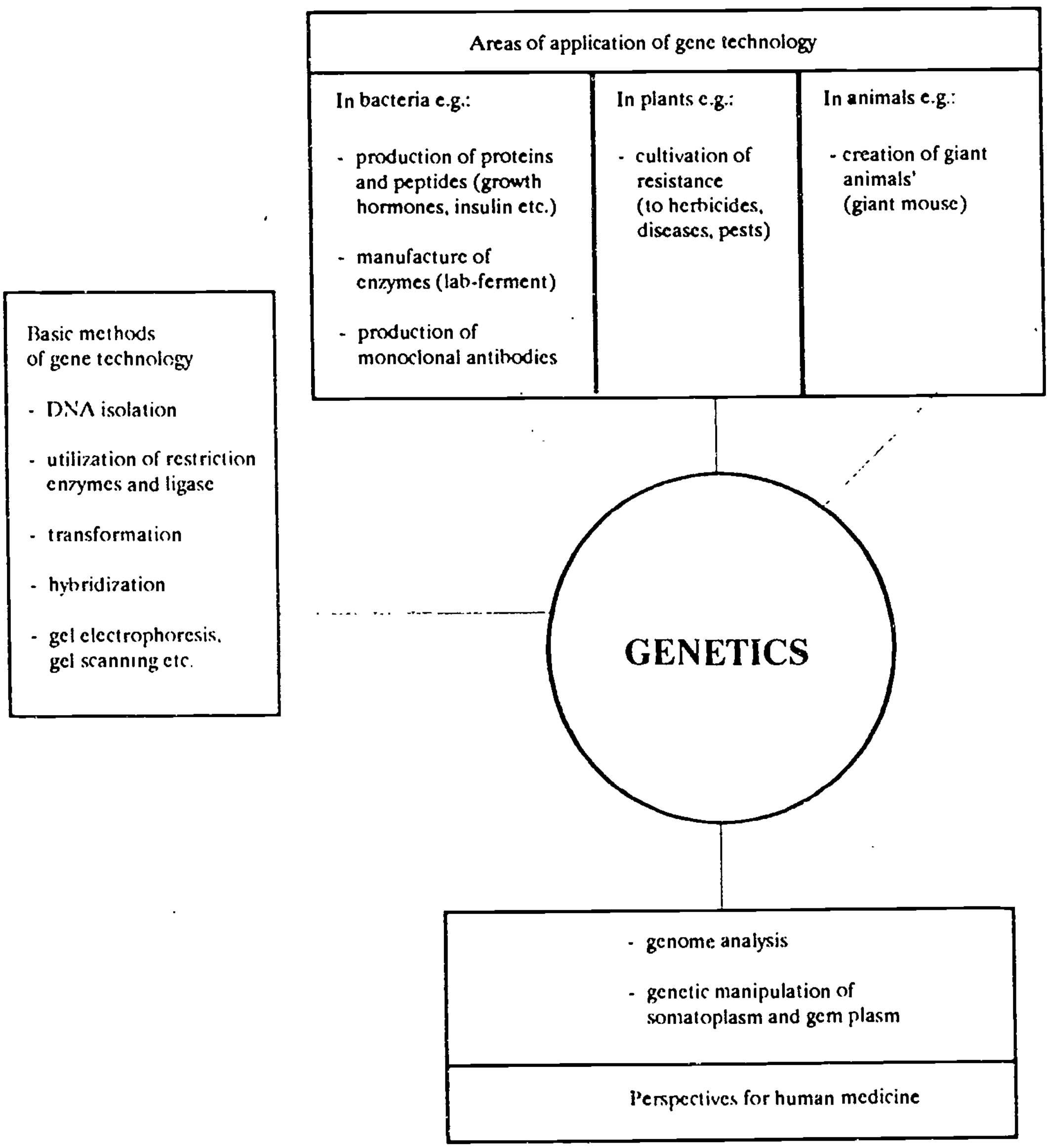


Figure 2. **Possible bio-technology themes for genetics in the higher grades of secondary education dealing with the use of organisms modified by gene technology**



These have been further elaborated into concepts and principles for the guidance of the curriculum developers, and include the following:

Microbiology

1. Micro-organisms: their variety and diversity with reference to habitat, size, form, structure, physiology, reproduction, multiplication rates and life-histories, through study of selected examples of bacteria, moulds, viruses, etc.
2. Ecology of selected micro-organisms with reference to human activities and other organisms.
3. All micro-organism are not harmful or pathogenic; many are very useful.
4. Some micro-organisms can be grown in large quantities to produce useful products from a wide variety of raw materials. In the process, large quantities of waste materials are sometimes generated.
5. Micro-organisms need suitable raw materials and environmental conditions to grow.
6. Micro-organisms: their use and role in industry and everyday life with special reference to:
   - Production of beer, wine, spirits, vinegar, proteins, vitamins, antibiotics, soya sauce, tofu, tempe, bread
   - Recycling of nitrogen and other nutrients
   - Nitrogen fixation, and bio-fertilizer, and organic fertilizers
   - Sewage and water treatment as well as waste management
   - Production of gas and liquid fuels as an alternative to finite fossil energy supplies
   - Dairy industry
7. It is possible to produce a cheaper, better, or different product by selecting more suitable alternative organisms, changing the raw materials or by improving the engineering process.
8. General microbiology techniques, procedures and their assessments with emphasis on safety.
9. Study of a cow's stomach as a fermentation tank converting plant materials to milk.
10. Bacteriocidal and bacteriostatic methods.

Future content

Other possible themes and concepts drawn from other disciplines may include:

Molecular Biology

1. Cell structure and function
2. Cell nucleus and its function
3. The structure of DNA and RNA
4. DNA replication
5. The genetic code
6. Protein synthesis
7. Gene technology

Genetics

1. Basic principles of genetics
2. Chromosomes as the physical bases of heredity
3. Improvement of crops and domestic animals through selective breeding
4. Hybridization
5. Linkages and recombinations leading to the understanding of spatial relationship of genes on the chromosome
6. Crossing over
7. Gene and genome

Biochemistry

Enzyme structure and function as a biological catalyst.

Recognition, isolation and purification of biological molecules.

Engineering

Basic principles in relation to developing cost-effective biological processes with reference to aseptic operations, reactor design (fermenters and immobilized bio-catalysts reactors), product recovery and marketing as well as use of simple instrumentation and process control.

Theory and Practical Skills in Bio-technology

1. Recombinant DNA technology
2. Monoclonal antibody technology
3. Bacterial plasmids
4. Restriction enzymes
5. Use of DNA probes
6. Electrophoresis
7. Fermentation
8. Physical processes for separation and purification of biological products
9. Safety measures
10. Cleaning and sterilization

Cell Biology

1. Animal and plant cell
2. Forms or shapes of cells as units of life
3. Cell reproduction and growth
4. Cell or tissue culture (it is possible to grow complete organisms from single cells; cell and tissue culture techniques may be used for storing germ plasm of useful genetic varieties)
5. Cell cloning

Applications of Bio-technology

1. Human applications (vaccines, diagnostics, gene therapy)
2. Agricultural applications (natural pesticides, growth hormones)
3. Industrial applications (energy, waste management, methane production, fermentation)
4. Ecological applications (natural biological control)

Genetic Engineering Technology

1. Genetic rearrangement occurs naturally

2. Natural genetic rearrangement is one source of the variation that occurs in nature.
3. Micro-organisms can act as vectors (carriers) for genetic information.
4. Genetic rearrangement results in the expression of new traits.
5. Genetic material is universal in the living world.
6. Experiments that involve potentially biohazardous material must be conducted in accordance with established safety measures.
7. Molecular biologists have learned how to control some of the processes of natural genetic engineering.
8. New techniques allow biologists to cut apart DNA and put it together in new combinations; i.e. recombinant DNA.
9. This recombinant DNA gives organisms new characteristics.
10. Recombinant DNA technology allows biologists to produce valuable biological products.
11. Not all the information in DNA is translated into mature mRNA.
12. Many genes exist in pieces, with coding regions (exons) separated by non-coding regions (introns).
13. The ability to manipulate genetic material quickly and efficiently raises important ethical, legal and policy questions.
14. All organisms contain nucleic acid.
15. The genetic code is a universal language.
16. The evolutionary relatedness of two organisms may be measured by comparing their DNA; greater variation indicates more distant relationship.
17. Genetic technology is a powerful research tool that has improved understanding of basic biological principles.
18. Progress in genetic engineering raises important and complex ethical issues for individuals and society.
19. Ethics is the study of right and wrong behaviour and of the rules that guide behaviour.
20. Reasonable people may disagree about what constitutes right and wrong behaviour.
21. Ethical analysis is a process of critical thinking; it is based on sound facts.

22. Often times there are no clearly *"right"* or *"wrong"* answers to ethical dilemmas.
23. Ethical positions often have implications for public policy. Public policies must generally meet several tests before they are likely to be successful.
24. Human DNA is highly variable; no two people have the same sequence of bases.
25. Variation in base sequences can create or eliminate recognition sites for restriction enzymes.
26. If the DNA from two people with the same restriction enzyme, is digested or *"chopped up"*, the variation in the DNA will result in different sized fragments for each person.
27. These fragments called RFLPs - can be used to detect the presence of disease-causing genes.
28. The genes for some disorders such as sickle cell anaemia can be detected directly. This requires knowledge of the specific mutation and restriction enzyme that cuts DNA at the mutation site.
29. Pieces of DNA that are on the same chromosomes are said to be linked.
30. During meiosis, homologous chromosomes exchange DNA in a process called crossing over.
31. During crossing over, pieces of DNA that are closely linked will be separated less frequently than pieces of DNA that are distantly linked.
32. Some RFLPs are closely linked to disease-causing genes.
33. If one can detect such an RFLP, one can predict that the disease-causing gene is also present.
34. The predictive power of linked RFLPs depends on how closely linked they are to the disease-causing gene.
35. Linked markers allow detection of disease-causing genes in the absence of knowl dge about the underlying cause of the disease.
36. The ability to detect disease-causing genes prenatally and in heterozygotes raises important ethical and legal questions.
37. Recombinant DNA technology permits the manipulation of genetic material in the laboratory.

38. Plasmids can be used as vectors to carry new genetic information into a bacterium.
39. Laboratory tests can determine whether the desired trait has been transferred to the bacterium.
40. Experiments that involve recombinant DNA must be conducted in accordance with established safety procedures.

Some General Concepts

1. Bio-technology has been in the service of humanity since early human history.
2. Genetic messages lead to variation in natural populations.
3. This variability can be accelerated and controlled by human intervention.
4. Modern or new bio-technology involves splicing genes to replace defective genes.
5. Gene therapy involves splicing of good genes to replace defective genes.
6. Antisense technology involves targeting and blocking the action of "*bad*" genes such as cancer causing oncogenes.
7. Bio-technology can solve as well as create problems and hence it should be guided by knowledgeable persons and decisions.
8. Bio-technology is in a state of flux and students should prepared for changes in both goals and techniques as more knowledge is acquired. Scientific research and development over the past years, particularly in molecular and cell biology, have generated possibilities of a multiplicity of new products and services or of old products produced in new ways. Likewise more research will further enhance these possibilities. The extent to which these become realities depends on complementary developments in process engineering and favourable commercial as well as socio-economic and cultural conditions.
9. The relative economic importance of various aspects of biological technology systems vary from country to country.
10. The use of living organisms in the economic context can sometimes give rise to social, ethical, political and legal issues that must be examined alongside the scientific and economic aspects of a potential development of biological technology.

11. Linking school teaching to the production of goods and services and particular to local industries related to food technologies, dairy products, green house technologies, pest control, sewage treatment water treatment, etc. gives it meaningfulness.

12. Each of the pathways through the bio-technology system generates, for young people, job and career opportunities that require a wide range of knowledge, aptitudes, skills, qualifications and experience.

Comprehensive awareness of the entire bio-technology system is not possible. However, for school children to understand some basics of bio-technology they should become familiar with the following concepts:

1. Inter-relationship and inter-dependence of humans and other organisms.

2. Diverse ways in which human life-style depends on the use of living organisms in the global economic context.

3. Growing and harvesting plants and animals on farms and in factories both traditionally and by using modern bio-technological techniques.

4. Farms, forests and industries are highly organized systems with diverse and changeable inputs of raw materials, capital and labour, linked to a complex marketing system extending throughout the world.

5. Selective breeding of animals and plants can produce desirable characteristics to meet high yields of good quality animal products and plants resistant to disease and parasites.

It is further reasonable to assume that during the course of school learning, in particular with reference to biology, most school children will experience at least some examples of selected bio-technological pathways from organisms to specific consumer products or services.

The following tables point to the possibilities of several new themes and concepts being linked to existing learning areas.

Future content

CHEMISTRY

Syllabus Topics	Reference to Bio-technology
CHEMISTRY OF LIVING THINGS	Genetics/recombinant DNA
ECONOMICS OF CHEMICAL PROCESSES	Use of enzymes of conventional catalysts/ chemical reactions (lower temperatures; fewer strong reagents; perhaps cheaper and safer).
ENERGY - fuels and resources; catalysis	Biomass; gasohol: biogas Use of enzymes
FOOD AND AGRICULTURE	a. Dairy industry - cheese; yoghurt b. Novel foods c. Improved crops - disease resistance, higher yields d. Pest control - use of fungi; genetic engineering e. Preserving foods - pickling
METALS - extraction from ores	Use of micro-organisms to leach out metals.
NITROGEN/AMMONIA	Nitrogen-fixing bacteria/reduction in quantities of fertilizers and energy used e.f. chemical fixation of nitrogen.
SOCIAL IMPLICATIONS	a. Novel foods e.g. Mycoprotein, SCP. b. Pollution and its control c. Recycling of materials d. Health and hygiene - antibiotics; immunology/monoclonal antibodies; synthetic hormones; new vaccines; interferons.
WATER	Water purification. Reservoir to water works to mains supply. Used water treatment. Sewage works to river.

SCIENCE

Syllabus Topics	Reference to Bio-technology
DISEASES AND THEIR TREATMENTS	Antibiotics; immunology/monoclonal antibodies: synthetic hormones; new vaccines; interferons.
ECOSYSTEMS	Importance of bacteria, fungi and algae, algae, the nitrogen cycle; nitrogen-fixing bacteria.
FUELS AND ENERGY	Biomass, gasohol and biogas use of enzymes as catalysts. Fermentation and alcohol production photosynthesis - ways of increasing the efficiency of plant to absorb and utilize sunlight energy and minerals.
REPRODUCTION, GROWTH AND CELLS	Genetic engineering. Cell and tissue culture.
SCIENCE AND SOCIETY	Genetics. Plant and animal breeding. Economics of processes. Comparison of the use of conventional plant with one using micro-organisms.
THE EARTH AS A SOURCE OF MATERIALS	Biomass; formation of oil/gas by bacteria; extraction of metals from ores by micro-organisms; renewable sources of materials when supplies of oil, gas and coal run out.
VARIETY OF LIFE	Micro-organisms; the importance of enzymes to all life.

BIOLOGY

Syllabus Topics	Reference to Bio-technology
BIOLOGICAL RESOURCES and their exploitation	Ethanol (gasohol), methane (biogas); biomass.
CELL BIOLOGY	Fermentation processes; nutrient requirements; SCP: cell culture.
CO-ORDINATION. Nervous and hormonal control	Use of plant hormones. Insulin production-genetic engineering. Sources of hormones used in medicine.
CROP AND LIVESTOCK PRODUCTION/BREEDING	Agriculture - embryo transplants; genetic improvement.
DIVERSITY OF ORGANISMS	Social, economic and technological impact of micro-organisms.
ECOLOGY	Microbial pesticides. Batch and continuous fermenters.
ENERGY - including biomass and nutrient cycles; energy flow through food chains	Ethanol; methane; biomass.
ENZYMES	Enzymes as products of fine organic chemicals with many industrial uses; enzyme inhibitors.
EVOLUTION - artificial selection	Selection of variants in antibiotic production; the emergence of resistant strains; drug resistance.

BIOLOGY (cont'd)

Syllabus Topics	Reference to Bio-technology
FOOD PRODUCTION - including processing	Dairy, fish and meat products; beverages; bakers yeast; food additives; novel foods; mushrooms; amino acids; vitamins; starch products; glucose and high fructose syrups; yoghurt manufacture.
HEALTH AND HYGIENE - including immunity	Antibiotics; diagnostic agents (enzymes, antibodies), enzyme inhibitors; steroids; vaccines.
HEREDITY/GENETICS/DNA, genes, chromosomes, mutation, genetic engineering	Recent advances in molecular biology in relation to biological industrial processes e.g. the use of genetically engineered microbes to make insulin human growth hormone.
MINERAL NUTRITION e.g. water cultures	Cell and tissue culture techniques; mineral requirements of microbes for suitable growth in fermenters.
PEST CONTROL	Microbial pesticides.
PHOTOSYNTHESIS e.g. efficiency of energy conversion	Biomass.
REPRODUCTION	Clones. Culture techniques.
RESPIRATION	Ethanol production - as an industrial chemical or in the alcoholic drinks industry.
SAPROPHYTES e.g. decomposition; recycling; carbon and nitrogen cycles	Sewage disposal; pollution control; ensilage and composting processes.
SYMBIOSIS/Mutualism	Rhizobium and other nitrogen fixing bacterial inoculants; yoghurt manufacture.
VARIATION	Artificial selection techniques, including genetic engineering in relation to a number of products.

Future content

As a further example of analysis of future content in biological sciences, the Group reviewed the broad implications in the content of bio-micro electronics, another growing edge in today's science.

Micro Electronics and New Biology

The exemplar content review indicated above, pointed to some selected content issues in the area of bio-technology, as a significant and vital component of future science content. However, the locus of movement in this selected content is essentially in the knowledge areas of biology and biochemistry. New biology has also entered as even newer and equally vital area of content, related to the integration of micro-electronics, information technology, robotics and bio-electronics. Through these new breakthroughs, human beings are emerging into a new mode of evolution itself, where human beings can change human beings and human life in a fundamental sense, to establish a new species, and challenge the very idea of "*naturalness*".

Already classical concepts like adaptation, evolution, identity, intelligence, learning, ecosystem, have undergone drastic modifications as a result of the impact of discoveries in computerized bio-microtechnology.

For example, integrated sensors are not merely in the vivid imaginations of scientists. There are already devices that convert non-electric inputs (e.g. sound, light, chemicals) into electrical impulses which may be fed into computers. They are robotic analogues of the five senses of human beings. In current advances in molecular electronics (bio-technology + micro-electronics), organic biosensors which recognize other organic chemicals, have been developed, such as the use of a monoclonal antibody as a sensor. Bio sensors now form components of artificial sense organs, and are used as control devices for heart pace makers. Field effect transistors are analogous to neurons of the human body, in that they respond to the electrical potential created by selected ions and are dependent on ions as an energy source. Such advances have pointed the way to "*bio chips*" or natural or synthesized organic molecules instead of silicon chips, in computers. Such research leads to the horizons where computer systems embody a spectrum of biochemical features that characterize biological systems and are creative, intelligent, thoughtful. Then it would be meaningless to say that biological systems are necessarily animate in a way that artefacts can never be. This leads to questioning the very basis of distinguishing life from non-life. The issue is further augmented by the fact that technically it is feasible (though not as yet practicable) to replicate inanimately much of what life is and does, through computerization. Yet human perception has potentially an objective cognitive and a moral identity. Whether this is the fundamental distinction between bio-robots and humans has to form an essential component of future content in this area.

A related area of content is artificial learning and intelligence, which will include concepts such as stimulus, perception, purpose, behavioral response, operation path and speed, information storage and multiple processing, problem solving. Such concepts would need to be redefined in the light of the advances of micro-electronics and computerization. The horizon of organically based biochip animate brains not being confined to biological systems is a feature to be dealt with in future content.

Of special importance in future content analysis, in areas of knowledge such as the above, is that the science content published and incorporated into the current "*tradition*" of science, is not necessarily the science that present-day scientists are working on, due to the substantial phase lag between content at the growth edges of science and published content. The analysis and inclusion of the former content becomes vital to the consideration of future content. Simultaneously, the growth edges keep changing as does the corresponding content. New strategies for incorporating this unique feature of inevitable *rapid* change in content, so different to the relatively leisurely changes in traditional content, have to be developed, parallel with the content analyses indicated previously. Such strategies would naturally alter drastically the entire processes and philosophies of curriculum development and implementation.

The types of fundamental questions and issues raised earlier focused on "*life*", "*naturalness*", animate/inanimate, cognitive/ethical, must necessarily raise pointed questions on ethics as it manifests itself as content in these new future content scenarios. The minimum locus of consideration would relate to such aspects as bio-microtechnology's potential for usurping "*biological*" or "*human*" intelligence; its potential for integrated biological and machine organization; its growing assistance to the control of human affairs. Such issues have prompted scientists and philosophers to hasten their consideration of the ethics involved in the entire fields of bio-technology and bio-micro electronics. Already such considerations have initiated new codes of ethics for the creations of such new areas, such as the well known Asimov's Laws of Robotics:

1. A robot may not injure a human being nor, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings, except when such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Deliberations of the Physical Science Working Group

There was a strong contrast between the requirements of participating countries in the Working Group, in respect of a physics syllabus. Some countries needed a syllabus that provided about 50 per cent of core topics and 50 per cent of options and electives, the contrasting requirement was 80 per cent core and 20 per cent options. It was apparent, after the earlier country presentations and their discussions, that the content of a physics syllabus was not in question, so the discussion turned to providing an extended core in physics and to nominate sufficient options to make up a *traditional core* if required.

In the following step in content analysis, an extended *core* is presented. As a bare minimum, a syllabus would follow the sequence from *KINEMATICS* to *MAGNETISM*. A more adequate coverage would result if a selection down to *OPTICS* was chosen. As a rough guide, it is suggested that each core topic take about five weeks of teaching time. In this way, one year of the syllabus would take a class down to *MAGNETISM* or *INDUCTION*, while the full core might take about 90 per cent of two years learning. This guide assumes that two traditional sciences of about six periods a week are taught. If countries chose to present only physics as science for one year, they should reach *MAGNETISM* in half a year instead of one year (they would need 10 to 12 periods a week).

Where 50 per cent options are chosen, they should not be left to a second year. The opening item *KINEMATICS* would also include some consideration of measurement and accuracy, the *LAWS OF MOTION* would include an historical component, while considerations of *POTENTIAL, ENERGY, KINETIC ENERGY AND WORK* would be extended to include national requirements. At this point, an option would be included; another option could well follow *OHMIC CIRCUITS* and by the time *INDUCTION* is reached classes would have gained the minimum sufficient core to enable them to draw freely from the options offered.

As only nine *special topics* are outlined (with others envisaged) it is not appropriate to suggest how long each option should take. It is difficult to imagine any option taking less than five weeks. However some (like *ELECTRONICS*) might flow quite naturally following *OHMIC CIRCUITS* so that the time expected to cover the materials becomes a matter for individual education systems to decide.

The prescribed core, with the addition of a topic on *ROTATION* and a selection of special topics, would probably cover the conceivable needs of countries in the region, including those that prescribe a national external examination for entrance to tertiary education.

A Physics Syllabus Core

KINEMATICS. This section may start with concepts of distance displacement and time. Distance would be astronomical down to interatomic to explain orders of magnitude. The distinction between distance and displacement helps introduce the topic of vectors. In measuring time, high precision is not required. The idea of accuracy would be introduced by this stage.

The concept of speed as a rate of change of distance, and acceleration as a rate of change of velocity, also introduce the fundamental ideas and application of calculus. The concept of integration may be followed informally, the change in velocity is the area under a plot of acceleration with time, while the distance is the area under a plot of speed with time.

The Kinematic equations follow and can be given as a useful model that can help describe motion where acceleration is not necessarily constant. Various examples of motion from the class environment should be considered and described graphically, as well as by using formulae.

FORCE AND MASS. The conditions for equilibrium include no external force and no torque, as rotation may not be further considered. The concept of moments could be examined at this point.

All familiar examples of forces can be explored and the concept of inertial mass considered for accelerating bodies.

LAWS OF MOTION. While the historical perspective of the development of Newton's Laws is interesting, students could be encouraged to consider these three laws in their own familiar intuitive environment. This topic may include an element of personal discovery.

In a similar sense, conservation of momentum need not be introduced using highly precise apparatus. Students can be given the formal principle after quite qualitative observations. The concept of impulse is a re-expression of one of Newton's Laws. A formal definition might not be necessary, although the term correctly used is useful. Again the conservation of Kinetic energy for elastic collisions is a concept that can be left to the discretion of individual teaching systems.

POTENTIAL ENERGY, KINETIC ENERGY AND WORK. The work-energy theorem of conservation of Kinetic and Potential energy (in a conservative system) can be found in one of the earlier Kinematic equations, while another will strongly suggest the second law generally attributed to Newton. It may be best to introduce these ideas of energy from previous familiar work. The idea of friction will have been introduced earlier and here, the concept serves to illustrate how, in general, energy can be lost from a non-conservative system.

Many teachers can leave the formal approach at this point and introduce enrichment material by identifying heat as energy and considering national needs, renewable and non-renewable energy sources.

ELECTROSTATICS. While Coulombs law is the logical opening for the topic of electricity, many demonstrations require special skill in a tropical environment. It might be expedient to mention types of charges, their conservation and then move quickly through to OHMIC CIRCUITS.

VOLTAGE AND ELECTRIC FIELD. The concept of electric potential as the energy per charge is very useful. The following concept of the electric field, as the negative gradient of the electric potential, will become a matter of discretion. Some classes will need to move quickly to circuits, while others will be able to reconsider vectors and the concepts of calculus.

OHMIC CIRCUITS. Many familiar applications of electricity can be considered in terms of Ohms Law. This topic should inevitably point to syllabus extensions. The concept of power (if not already used) can be introduced in a familiar setting at this point. The basic ideas of the potential divides and current division carry through to advanced electronics. These can be simply considered in terms of Ohms Law.

MAGNETISM, FORCE AND FIELD. Unlike ELECTROSTATICS, there is much more scope to demonstrate this phenomena in the classroom. If the concept of the electric field was previously done in a cursory fashion, it can be reinforced by comparison with the magnetic field. Magnetism is a natural and fascinating phenomenon that provides opportunities for pupil discovery. The magnetic field generated by a current is quite weak and more than 10 Amps are normally required for classroom experimentation. These currents are available from 12V car batteries, but careful supervision is needed not so much to protect students, as to protect equipment.

The magnetic force on a moving charge is an abstract concept that can be introduced as a simple realistic extension of the magnetic force on current carrying conductor.

INDUCTION. This is a familiar effect in many areas of technology. However the subject can be overdeveloped and cause confusion. Depth of treatment is a matter of choice. Lenz's Law and the concept of magnetic flux would represent a good coverage of theory, while more practical classes can explore and study electric motors and generators. In the absence of rotation, the derivation of a formula for the torque on a current carrying loop in a magnetic field, may be taking content too far.

CIRCULAR AND HARMONIC MOTION. These topics may have been introduced under KINEMATICS. Again circular acceleration may have been used to consider satellite motion. If not, it can be done at this point. While equations for circular motion follow naturally from vector differentiation, this approach might not be suitable for all. If an easy approach cannot be used, the derivation may be left out. The projection of circular motion to produce harmonic motion is useful and important to students continuing on in physics or engineering.

The discovery of a sine curve as a numerical solution to the harmonic equation is mentioned elsewhere. This approach is suitable for most classes, especially those interested in computing, even though a computer is not necessary.

WAVES. While most physics classes consider regular harmonic phenomena, this approach can restrict the number of familiar environmental examples. The initial approach would consider periodic phenomena such as annual and diurnal cycles. The basic wave equation applies to a fixed speed and period and can be illustrated by familiar examples.

Wave propagation, reflection and refraction can be explored using Hughen's approach. A closer discussion of the nature of electromagnetic waves can be used to explain interference and diffraction, while acoustic waves can also provide interesting effects.

OPTICS. This topic deals with light in particular and much valuable ground work can be laid in the previous topic. Kits of lenses and mirrors should be available for classrooms in all regions. The traditional approach considering first mirrors then lenses, ray diagrams and the familiar formulae has not been superseded. If teachers are becoming concerned over matters such as sign conventions and real or imaginary rays, they may have gone too far for this level of learning.

Much *enrichment material* can be added with optics, ranging from *astronomical observations* to *light sources* and *lasers*. For courses that offer most of this syllabus core, it really is necessary to offer special topics at this point.

KINETIC THEORY. A number of initial observations can be made regarding the properties of gases before numerical derivations are examined. It is virtually impossible to attach the original discoverers name to each gas law, so a discovery approach is more appropriate than a historical discussion. The ideal gas equation is needed for chemistry and can be simply given as another useful physical model to explain gas behaviour.

TEMPERATURE AND HEAT. As with KINETIC THEORY, there may be overlap with a chemistry syllabus in this topic. This should not be a problem as two approaches to the same topic should ease the burden and reinforce the learning.

Working through a simple variant of the kinetic gas formula will serve to reinforce earlier concepts of the physics syllabus. The equating of internal kinetic energy with temperature remains a familiar and significant step in physics that should be of interest to advanced classes.

The concepts of heat capacity and heat transfer can be taken up by any class as a starting point for a study of heat in the physical environment, which can provide an enrichment topic.

ATOMIC STRUCTURE. This topic, along with the last two, may also overlap with a chemistry syllabus, and for this reason they appear last in the core physics material. The topic has been included as it provides a starting point for a number of special topics is LASERS, PROPERTIES OF MATERIALS, NUCLEAR PHYSICS OF PARTICLE PHYSICS.

The classes which require this subject in the core syllabus will have a particular commitment to physics as a serious study. The identification of specific atomic properties at the turn of the century would be given and the Bohr model of the atom would be considered quantitatively. These topics will give considerable reinforcement to earlier topics in this core. Once this initial territory has been crossed, there remains a vast landscape for further study by physics students.

Some Special Physics Syllabus Topics

LASERS

Requires: WAVES, OPTICS, ATOMIC STRUCTURE
Can extend to interdisciplinary areas.

PROPERTIES OF MATERIALS

Requires: ATOMIC STRUCTURE

Can extend to interdisciplinary areas.

One particular type of material could be studied in detail.

SUPERCONDUCTIVITY

Requires: MAGNETISM, OHMIC CIRCUITS

A phenomenological approach only, useful in towns and cities where Hi-Tech superconductivity is available. Can be interdisciplinary with chemists.

NUCLEAR PHYSICS

Requires: ATOMIC STRUCTURE

Ideally this topic would include fission and fusion reactors and can become environmental.

PARTICLE PHYSICS

For physics students only.

RELATIVITY

This topic can be used to extend KINEMATICS and even LAWS OF MOTION. For less motivated students, elements of relativity may be included with the core if students want some knowledge of RELATIVITY. Otherwise this is a topic for committed physics students.

ELECTRONICS

Requires: OHMIC CIRCUITS

Electronics is a subject in itself. A physics class in a secondary school could choose to study either amplifiers or binary logic and simple digital circuits. Classroom kits for the latter are becoming available but will be most useful in larger towns and cities.

THERMO DYNAMICS

Requires: KINETIC THEORY, TEMPERATURE AND HEAT

This subject is interdisciplinary and environmental. However it requires considerable physical abstraction.

PHYSICAL ENVIRONMENT

There are many environmental measurements which require the particular skills of physicists. Obviously this is an interdisciplinary subject. Many regional needs can be met by studying, for example, meteorology or the flow of water.

CONTEMPORARY DEVELOPMENTS

Superconductivity, especially the study of high temperature superconductors, is a typical example of a topic that might suddenly emerge and hold student interest for some time.

As with bio-technology, lasers represent a likely new content area to enter science and technology education at secondary level in the future. Hence a scope map is provided below, to help identify intrinsic content as well as supportive content that may need to be considered prior to curriculum development.

Lasers - A Scope Map

Optics is a traditional part in the physics text book. But usually in the secondary school physics course attention is only paid to geometric optics and wave properties of the light. Diffraction and interference phenomena are taught to explain or verify the wave nature of light. It was reasonable before the invention of the laser. At that time, the most important optics industry was the lens making industry. The existence of the laser has changed the situation dramatically. The fantastic and attractive laser stimulates scientists and engineers to find so many ways of using the laser. Now lasers have been used widely in industry, such as in building construction, mineral pit drilling, ultra-precise measurement, military purposes, optical communication, as well as in medical treatment. The opto-electronic industry has grown up to be one of the most important parts of the modern high-tech industry.

Light Source

1. General introduction to light sources (structure, principles, characters)
   a) Heat radiation source: Tungsten lamp bromine tungsten lamp, etc.
   b) Gas discharge tube: Day-light lamp, neon lamp, etc.
   c) Solid state light source
2. Properties of light sources
   a) Efficiency of light source (Power converting efficiency)
   b) The relation between the temperature and the colour of heat light sources

Laser and Its Applications

1. The general introduction to lasers:
   a) The structure and the working principles of the laser (take *He-Ne* laser as an example)
   b) The properties of laser
      - Monochromacity
      - Dictionality
      - High brightness
2. The applications of laser
   a) Application in industry

   b) Applications in agriculture
   c) Optical communication
   d) Application in meteorology
   e) Application in medical treatment and biology
   f) Application for military purposes

3. Holography
   a) Principles
   b) Applications

The content analysis regarding some scientific principles involved may be illustrated (only as an example) by the following.

Early Work Related to Laser Principles

The laser owes its beginning to the maser developed by C.H.Townes at Columbia University. While working on the absorption of microwaves in ammonia, Townes used as the basic principle of his work, the fact that ammonia may be considered as having two energy states under some appropriate conditions.

A physical model of the ammonia molecule may be visualized as a pyramid with an equilateral triangular base. At the corners of the equilateral triangle, there is one hydrogen atom each, while the nitrogen atom occupies the apex of the pyramid. When subjected to an external electric field in the vertical direction (E), the plane of the hydrogen atoms adjusts itself in the plane perpendicular to the direction of the applied electric field. The nitrogen atom has the possibility of being on top or under the equilateral triangular base. The two configurations correspond to two states or represent two physical orientations of the ammonia molecule in the applied electric field.

The ammonia molecule has a permanent dipole moment (p) due to the tendency of electrons to lie closer to the nitrogen atom than to the three hydrogen atoms. This situation leaves the nitrogen atom slightly negative and the hydrogen atoms slightly positive. In the configurations depicted, the energy of the ammonia molecule with the dipole moment in the anti-parallel direction with the applied electric field is 2pE greater than the ammonia molecule with the dipole moment in the parallel direction with the applied electric field.

Townes arranged to have a large number of the ammonia molecules in the higher energy state before he forced these ammonia molecules to flip their dipole moments to the lower energy state. By doing so, Townes obtained a coherent and thus very powerful beam of microwaves with the frequency of 24,000 MHz.

To separate the ammonia molecules in the higher energy state from the rest in the other, a beam of ammonia molecules was sent through a hollow cylinder made up of negatively charged dielectric rods. Close to the axis of the cylinder, the electric field was very weak and came close to zero, while away from the axis, the field was very strong. The ammonia molecules with the dipole moment parallel to the direction of the radial field (lower energy state) were pulled away from the cylinder and lost, while those with the dipole moment anti-parallel to the direction of the radial field (higher energy state) were pushed towards the axis and allowed to continue their motion along the axis into the waveguide cavity. Almost all of the ammonia molecules entering the cavity were in the higher energy state.

By hitting these higher-energy state molecules with a microwave beam having the frequency of 24,000 MHz, all of the excited molecules all at once gave up their energy in the form of a coherent microwave at the same frequency. The input microwave at 24,000 MHz was in effect amplified with extreme fidelity, hence the acronym "*maser*" which stands for microwave amplification by stimulated emission of radiation. The ammonia maser even in the '*crude*' form will not amplify a microwave signal that differs from its 24,000 MHz frequency by more than 3 to 5 kHz.

The ammonia maser was quickly followed by the development of solid-state masers using para-magnetic substances as maser materials.

From Maser to Laser

It was a matter of time before the principle of the ammonia maser was applied to the visible part of the electromagnetic spectrum. Since the signal to be amplified is in the visible range of the spectrum, the device is called the optical maser. The word was eventually abandoned in favour of the word "*laser*", which is the acronym for light amplification by the stimulated emission of radiation.

In constructing the laser, it is not possible to work with the two energy state system. The difficulty lies not in the separation of the higher energy state from the lower energy state of the laser material. Once the atom is excited to the higher energy state, it remains there for a period of about 10^{-8} seconds before returning to the ground state. This order of time is not long enough to have a reasonable accumulation of the excited states.

The way to overcome this problem is to work with a three energy level laser material such as ruby. This is a crystal of aluminum oxide with chromium impurity of the order of 0.05 per cent by weight.

Once the chromium atoms are excited from the ground level E_1 to the upper energy level E_2 , they can return to the ground level in two different ways. The first is to make '*spontaneous*' transition to the ground state within the period of 10^{-8} seconds and emit photons of the same wavelength. The second is to make '*spontaneous*' transition to the lower energy level E and emit photons in the infrared region. The chromium atoms can remain at the energy level E for several milli seconds which is eternity compared with 10^{-8} seconds. The energy level E_3 is known as the metastable state.

The chromium atoms in large numbers can be put in the energy level E_3 in a matter of a few milliseconds. This process is known as the population inversion, i.e. there are more chromium atoms at energy level E_3 than at energy level E_1.

In the ruby laser, one needs to have the optical box which functions like the waveguide cavity. The dimensions of the ruby rod are several million times the wavelength of light. Since each end of the ruby rod is fixed with a semitransparent mirror, a photon traveling back and forth has increasing chance to interact with the chromium atoms.

To raise the chromium atoms into E_2 energy level, a xenon flash tube emitting pulses of light lasting about one half to two milliseconds is used. Excited chromium atoms then drop to E_3 energy level. As one of these chromium atoms emits a photon with 6943°A wavelength in the direction parallel to the axis of the rod, interaction between this photon and another chromium atom in the E_3 energy level takes place. The interaction causes the chromium atom to undergo stimulated emission of a photon of the same wavelength. The second photon is coherent with the first. As this mechanism goes on, the ruby rod grows in intensity due to more and more photons at 6943°A are given off by stimulated emission. As the intensity of the coherent light becomes intense enough, a burst of the coherent light will leave the semitransparent mirror on one side of the ruby rod.

Types of Laser

Various types of laser have been produced using gas and liquid laser materials. Different means of pumping atoms at the ground level into higher energy states and then metastable states have also been used. Thus we have lasers which are sun-pumped, chemical-pumped and even explosion-pumped.

Perhaps the laser that is different from the rest is the so-called injection laser. Its principle is also very simple.

When an external voltage is applied to the N-P junction semi conductor, electrons in the N-type region start to move towards and into the P-type region. At the P-type region, the electrons drop into holes and some of recombination energy is given off in the form of a photon. If the applied voltage is large enough, a large number of electrons and holes become concentrated in a very narrow region of the order of 1/10,000 of an inch wide on the P-side of the junction. A photon emitted stimulates the emission of more photons by accelerated recombination between injected electrons and holes.

Applications of Lasers for Developing Countries

The remarkable properties of lasers have lent themselves to a wide range of possible applications from basic science to medicine, biology, radar communication, microwelding, weaponry and so on.

The research and development work on the laser need not require a large investment and is within the means of many developing countries. Some areas of research work on lasers offer good opportunity for scientists to participate.

While the above scans the possible content in regard to the principles on which the laser is based, equally importantly it also points to the pre-requisite knowledge the learner must have to be able to comprehend the above.

Chapter Three

LEARNING/TEACHING OF FUTURE CONTENT

The Biological Science and Physical Science Groups continued their separate discussions, with focus on the learning and teaching of the new science and technology content, and on linking the existing content to the new content.

Sources

Throughout the workshop, and in the group sessions, the need to establish effective contacts for academic and technical resources, was stressed. Unlike earlier curriculum reforms, which involved the updating of single discipline content (content of physics or chemistry or biology), several of the new content areas were inter-or multi-disciplinary (such as biotechnology, materials science, space science), and also involved technology as well. Thereby, it was not sufficient to consult only the earlier resource persons, such as professors at universities (in physics or chemistry or biology). Very frequently, several subject-matter experts had to be referred to, and previously unused mechanisms for consultation were needed to be established.

The seekers and receivers of these resources, usually science and technology curriculum development personnel, were often themselves single discipline specialist. These persons would have to expand their content horizons to match the inter- or multi-disciplinary nature of the new content to be able to seek for effectively, and receive and use constructively, the new content aspects from the expanded group of content specialists.

The curriculum specialists have also to be acutely aware of aspects like the safety of the students in conducting learning activities, which in turn would involve a still wider group of resource persons.

Many of the new content areas have, intrinsic to them, significant dimensions of values and ethics and possibly legal aspects as well, which have to be clarified before designing the learning and teaching sequences. Once again, the potential source person "*net*" has to be cast even wider.

With such a variety of needed source persons, and many of them likely to be having little spare time for frequent consultations, the entire resource seeking and receiving operation would need to be carefully and systematically planned for. The planning needs to include the recognition that many of the resource persons would not be pedagogists, so that their content suggestions have to be reprocessed for student learning/teaching purposes.

While printed sources may be available, the vast content expanse of the new learning areas, and the rapid changes in these content areas, underline the urgent need for prioritizing the content requirements.

Prerequisite Content

In several of the new content areas of science and technology, a "*coming together*" takes place of content from several discipline areas. Some of these content components may well be beyond the scope of coverage currently at secondary level, and may demand an inordinately long time to acquire (if at all suitable for this level because of abstraction or sophistication), before proceeding with the learning of the new science and technology content. Yet, while it is certainly possible to provide for a general appreciation of a new technology, appreciation with understanding must needs require the prior learning of the prerequisite content components. This could become a serious problem, especially if the new content areas are learned in out-of-school situations such as science clubs. Wise judgments would be required in deciding the kinds and extent of prerequisite knowledge required for proceeding in the learning/teaching of new science and technology content. If the model of core-cum-optional courses is chosen, corresponding implications must appear for the new core design.

Entry Points

Practical considerations would point to strategies in the learning/teaching situation which use existing content specifications at secondary level. The previous content analysis of the new learning area of Bio-technology, Chapter Three, indicated specific, currently available content analysis situations, which could form entry points for the new content. Similarly, curriculum designers would need to identify, in the learning situations, equivalent entry points. The possibilities of entering the learning of a number of new content areas, via fairly "*standard*" learning sequences currently in use in several countries, but now enriched with new dimensions for moving into these new areas, as well as into such significant affective aspects as ethics and values, and concern and responsibilities about fellow human beings, provide concrete starting points in the designing of learning sequences, but with attributes quite different to those that were identified in the earlier reforms since the 1960s, when content was essentially confined to single well-established disciplines.

Designing Learning/Teaching Activities

At least as much effort would need to be devoted to the design and development of learning/teaching activities, investigations, experiments related to the new content areas, as for the detailed content analysis. Past experiences in curriculum change in science have indicated that this design and development work has to start very early in the curriculum development operation if such activities are to be made available when the learning sequences derived from the content analysis are being considered.

Some, at least, of the new content areas, have already such activities in use, though usually at higher levels of education. These would need to be reconsidered in terms of their feasibilities of use in secondary level schools. Among the many possible considerations, the reduction of sophistication by decreasing precision, has provided constructive directions for design. This implies that curriculum development designers would need to work with content specialists, (such as from universities and other institutions of higher learning and research) to decide the extent to which such reduction of precision would be possible without damaging the accurate learning of the concepts involved. It should be noted that when the new science education reforms of the 1960s were being designed, and updated content introduced together with hands-on learning activities for students, similar actions had to be taken (for such content areas as equilibrium, structure in chemistry; waves in physics; heredity and DNA/RNA in biology).

For various purposes, such as for wide commercial use, some of the previously purely university or research laboratory activities may have been absolute already. Needed apparatus or chemicals or media may be in the market now. In some countries in the region, the markets have such new resources as culture media, electronic components, and even toys, which embody new science and technology content, at relatively low cost.

Also, in several countries, development departments such as Agriculture, Forestry, Fishery, Small Industry, for their own extension services for their target populations, have developed activities based upon the new content of science and technology (e.g., cloning of plants). These are also valuable resources to be considered.

For the international market, some developed countries have produced kits that embody the new science and technology content (such as in bio-technology, lasers, computers). These sources may be considered during the design operation.

It is not always necessary for only the curriculum development centres to be involved in such design of learning/teaching activities. The creative energies and talents of teachers and pupils may be mobilized by stimulating design work by these vast numbers, through such mechanisms as science and technology fairs and competitions, which have now become a regular feature in several countries in the region.

A few countries that have already initiated work in designing learning/teaching activities related to new content in science and technology, may be willing to share their products and expertise with other countries in the region, through such mechanisms as the UNESCO PROAP/APEID network.

To stimulate action, and to illustrate concretely the above tasks, the following "*desophisticated*" example in bio-technology, applied to plant tissue culture, is provided by the Workshop.

PLANT TISSUE CULTURE:
An example of an Activity in Bio-technology

Introduction

The techniques of plant organ, tissue and cell culture, are now established in many research laboratories throughout the world, and are being used in various areas of plants science. Methods have been developed to propagate virus free plants by using shoot tip culture. The regeneration of plants from callus culture have proved commercially useful. Somatic hybridization, formed by the fusion of protoplasts, has made hybrids which would be impossible to create by conventional methods. These techniques have been, and can be used, to investigate a variety of botanical processes, as well as to improve crop plants. They are now important basic experimental skills required by a majority of botanists.

The methods of plant organ, tissue and cell culture, have been successfully and widely used in the micro-propagation of plants, in the production of certain chemicals, in the improvement of agricultural crops such as disease resistant plants, in inducing genetic variability, and in making hybrids between unrelated species. Since the techniques have been well worked out for many crop species, they provide a powerful tool for plant biotechnology, are relatively easy for inexperienced students to perform, and are relatively inexpensive to conduct, it is recommended that tissue culture be considered for introduction to students at secondary level.

Pre-knowledge Requirements

Basic knowledge of sterilization and aseptic techniques, and solution preparation are required. Knowledge regarding plant tissue, such as shoot tip, cambium, parenchyma, vascular tissues and plant nutrition are also required.

Objectives

At the end of the activity, learners should be able to:

1. Define and give examples of terms such as callus, re-differentiation, growth differentiation.
2. Determine growth of tissue such as callus.
3. Indicate which hormone is active in promoting callus.
4. Recognize the problem of contamination, the existence of air-borne micro-organisms, and ways to prevent such contamination.
5. Explain cell growth in vitro, and factors needed.

Isolation of Explants, Establishment and Maintenance of Callus of Carrot (Daucus Carota)

Explants isolated from the tissues of higher plants and brought into culture, like excised organs, require a nutrient medium consisting of a mineral salt mixture, a carbon source, (usually sucrose) and vitamins. In addition, plant hormones (auxins and cytokinins), or their synthetic counterparts, are required to initiate and maintain cell division. Occasionally other organic compounds are supplemented, to ensure that the excised tissue gives an established callus. On suitable media, tissue fragments from most dicotyledonous plants, particularly those containing meristematic cells, (for instance, the cambium or shoot meristem), will start to proliferate rapidly. Less frequently, some of the mature cells will also divide and subsequently become involved in callus formation. Objects best suited for such activities are explants cut from the tap root of carrot (Daucus carota). These may also be used to test the effects of different compounds of the culture medium on induction and subsequent growth of callus from explants.

Materials and Equipment

Sterile Items

1. 1.2 rimless culture tubes (150 x 25 mm) containing 10 ml of 0.8 per cent agar medium + 5 x 10^{-8}g/ml 2, 4-D sloped at an angle of 25°
2. 20 sheets of tissue paper (200 x 200 mm)
3. 10 petri dishes 90 mm in diameter, either glass or plastic
4. 31 of sterile distilled water contained in 3 Erlenmeyer conical flasks (1,000 ml)
5. 50 sheets of aluminum foil (100 x 100 mm)
6. 2 beakers with lids (90 mm in diameter and 50 mm deep)
7. 2 pairs of forceps (120-150 mm)
8. 3 scalpels (c.150 mm)

Non-Sterile Items

9. 2 tap roots of carrot (Daucus carota) at least 200 mm in length and 40 mm in diameter. The plant material may be purchased at the local market or preferably grown in open ground, in sandy soil in the garden. Most varieties will respond to the culture procedure employed in this activity.
10. 2 racks, preferably plastic or metal, to hold 12 culture tubes (150 x 25 mm) at an angle of approximately 25°
11. 1,000 ml of a solution of sodium hypochlorite approximately 20 per cent (v/v), (commercial bleach preparations can be used at a dilution of one part to five of water)
12. 1 waterproof marking pen
13. 1 glass beaker (1,000 ml)
14. 1 analytical balance for determining the fresh weight of the cultures

15. 1 Bunsen or ethanol burner
16. 1 Erleneyer flask (150 ml) containing 100 ml 95 per cent ethanol
17. 1 roll of parafilm
18. 1 small nylon nailbrush

Procedures

Use regular shaped, undamaged and clean carrot roots. Scrub the carrots with a small nylon nailbrush under running tap water, to clean the surface wall, and peel. Place the carrots (trimmed to about 100 mm in length) in a 1,000 ml beaker, cover with the solution of sodium hypochlorite and leave for approximately 30 min. During this sterilization procedure, mark each culture tube with the number of the carrot root, the medium and the date. Transfer the sterilized carrots to the sterile room, making sure the UV lights are switched off before entering. (Powerful UV rays are harmful to the eyes and skin!) Wipe the working table clean with 70 per cent ethanol. Throughout the manipulation sequence, forceps, scalpels, and other small instruments must be kept in 95 per cent ethanol and flamed thoroughly before use. (Ethanol is inflammable, take great care during flaming!) Wash the carrots three times with sterile distilled water, agitating the beaker to remove completely the hypochlorite, and dry using the tissue paper. Transfer a carrot with 20 mm removed from each end, to a sterile beaker, and cut a series of transverse slices 1 mm in thickness from the carrot root, using a sharp scalpel. Transfer each slice to a sterile Petri dish and cut explants 4 mm x 4 mm square across the cambium so that each piece contains parts of the phloem, cambium and xylem. Size and thickness of the explants should be uniform, so that a comparison can be made of the fresh-weight of the cultures after 4 weeks of growth. (Weigh 10 freshly isolated explants in order to determine the average fresh-weight). Repeat this procedure until sufficient explants have been accumulated for the activity. Always replace the lid of the Petri dish after each manipulation. Remove the closure from a culture tube and flame the uppermost 20 mm of the open end. While holding the tube at an angle of 45°, transfer (using forceps) two explants onto the surface of the agar, taking care that the root pole is touching the medium. Seal each tube immediately with a square of aluminum foil which has been flamed, before and after it has been placed on the tube. Always flame the forceps between transfers. Repeat this procedure until all of the culture tubes have been used. Place the culture tubes in the racks and incubate in the dark at 25°C.

Sub-culture of Callus, Materials and Equipment

Sterile Items

1. 5 carrot cultures initiated from explants 4-6 weeks ago or an established callus sub-cultured 3-4 weeks previously
2. 12 rimless culture tubes (150 x 25 mm) containing 10 ml of 0.8 per cent agar medium + 5 x 10^{-8}g/ml2, 4-D sloped at an angle of 25°
3. 20 sheets tissue paper (200 x 200 mm)
4. 5 Petri dishes, 90 mm in diameter
5. 50 sheets aluminum foil (100 x 100 mm)
6. 3 pairs forceps (120 - 150 mm)
7. 3 scalpels (150 mm)

Non-Sterile Items

8. 2 racks, preferably plastic or metal, each to hold 12 culture tubes (150 x 25 mm)
9. 1 waterproof marking pen
10. 1 Erlenmeyer flask (150 ml) containing 100 ml 95c ethanol
11. 1 roll parafilm
12. 1 Bunsen or ethanol burner

Procedures

Remove the culture tubes one at a time from the rack, and flame the top 20 mm before removing the explants/callus and placing them in a sterile Petri dish. It is preferable to accumulate six explants/callus pieces in each dish. Usually after 4 weeks in culture, the explants incubated on medium with 2, 4-D have formed a substantial callus, and each piece should be divided into two or three pieces of not less than 5 mm x 5 mm. The cells on the lower side of the explant towards the centre are frequently necrotic in appearance and not suitable for sub-culture.

These necrotic areas should be separated and discarded. Ensure that the lid of the Petri dish is placed after each handling. Transfer the developing explant/callus to a fresh medium in a culture tube. Flame the top 20 mm of the tube containing the fresh medium and discard the aluminium foil cap. Using flamed forceps, remove two pieces of callus the place these apart on the surface of the medium towards the end of the tube. Take a square of aluminium foil and close the open end of the culture tube ensuring that a good seal is formed, flame the foil end place the tube in the rack. This procedure should be repeated until all the cultures have been transferred. Prolonged culture of carrot tissue produces large calluses. The procedures described for the first subculture of the developing callus are similar to those used for the routine subculture of established callus lines with a transfer period of 4 weeks.

Scheduling

Event Timing
Isolation of fresh explants from carrot root Day 0
First subculture Day 28
Marked proliferation of callus c.Day 42-48
Isolation of established callus c.Day 91-98
Transfer period of established carrot callus 4 weeks

Recording of Results

Write down details of the activity in a note book, recording the starting date of the activity, the duration, number of cultures, of contaminations and the different treatments employed. Make visual observations of the cultures at weekly intervals for 4 weeks, recording changes in the morphology of the culture. Determine the fresh weight of the cultures initially, and after 4 weeks of growth.

Questions and Comments

From which tissue of the freshly isolated explants does the callus originate? Do all the explants grow at a similar rate? Can liquid culture be used? If so, what should be provided?

Sterilization

Sterilize metal instruments, glassware and pieces of aluminium foil after wrapping in aluminium foil or by heating in a hot air over at 150°C for 3 hours. Sterilize the culture media, distilled water and other stable mixtures in glass containers closed with cotton wool plugs and capped with aluminium foil in an autoclave at a pressure of 15 psi for 15 min. Paper towels and tissue paper should be wrapped in aluminium foil and autoclaved. Solutions of chemicals that will change upon autoclaving can be sterilized using a milipore filter.

Culture Medium

Chemicals	Concentration (mg/1)
Macroelements	
$CaCl_2.1H_2O$	440.0
$FeSo_4.7H_2O$	27.8
KH_2PO_4	170.0
KNO_3	1,900.0
$MgSO_47H_2O$	370.0
Na_2EDTA	37.3
NH_4NO_3	1,650.0
Microelements	
$CoCl_2.6H_2O$	0.025
$CuSO_4.5H_2O$	0.025
H_3BO_3	6.2
K1	0.83
$MnSO_44H_2O$	22.3
$Na_2MoO_4.2H_2O$	0.25
$ZnSO_4.7H_2O$	8.6
Sucrose	2% (W/V)
Nicotinic Acid	0.50
Pyridoxine	0.1
Thiamine HC1	0.1
Clycine	3.0
2, 4-D	See Text
Kinetin	See Text
Agar	0.8% (W/V)
pH	5.8

The Use of Calculators in Secondary Schools

It is likely that the new science and technology content like the current science, especially physics, would continue to make demands in mathematics and computing, thereby requiring students to have a number of prerequisite competencies in this area.

The nature of the demands need not be interpreted to mean that computers are required for each school, to permit the achievement of these competencies.

A consideration of typical secondary science syllabuses suggests that a programmable calculator will serve adequately for the most advanced topics and calculations. If students are to develop a feel for numbers and quantities, they should construct and test their own algorithms, and be left to explore the consequences of simple mathematical procedures. The cost of supplying suitable calculators is not high; if a scientific calculator is worth one textbook, a programmable calculator of 100 programme steps and 10 memories is worth two textbooks. Motivation is a key to learning. Essential mathematical tools are quickly grasped in the context of real physical problems. Very often, a programming language can be learned and used in a matter of days if it is needed for a genuine problem. Similarly statistics cannot be easily understood outside a context of real life problems. It seems imperative that some numerical computing be used in the context of physical problems. The equipment needs will be modest at the secondary level; a programmable calculator, a pencil, an eraser and some paper, including graph paper. With this minimum set, the students should become thoroughly involved in computing.

There are three important areas of numerical computing that can be introduced with a secondary school physics syllabus. The first is polynomial curve fitting, especially using straight lines to fit appropriate experimental data. The second is numerical differentiation and integration, essential because senior physics depends so heavily on calculus. The third possible area is the use of a mean and a deviation to describe the randomness of data points. These statistical concepts should be applied with common sense rather than with further sophistication.

Least-Squares Fitting

Least-squares fitting of a straight line or the linear regression of experimental data (with a high correlation) can be provided as an incentive to collect and refine data. Some appropriate experiments that provide data are: the determination of a focal length, the change of speed with constant acceleration or distance with constant speed, and the measurement of elasticity. A logarithmic linear fit can be used to study the streamline emptying of a column of fluid or the half-life of a newly leached radioactive decay product. These last two examples will deviate from a logarithmic-linear line for obvious physical reasons.

When all the data is plotted, complete with estimated uncertainties, and a best fit line has been found, commonsense judgements will usually give better estimates of the parameter uncertainties than any further statistical analysis.

If students are to understand the least-squares analysis, they should be able to appreciate how and why the various formulae are developed. There are several approaches within the scope of senior physics students. The usual derivation of the formulae from a best fit polynomial is suitable for classes with a strong calculus background, and these classes should also be able to develop strategies for fitting quadratic curves. Other students who are less familiar with calculus, could start with the axiom that mean bivariate values give a point on the line of best fit. From this point the x or y variance of lines with different slopes can be explored.

Numerical Integration and Differentiation

It is doubtful whether any student can come to terms with physics without understanding the concepts of integration and differentiation. Most traditional syllabuses start by describing motion. The reason for this approach is simply to illustrate the underlying calculus. As students become familiar with the techniques, they will be capable of exploring the solutions of second-order differential equations, a topic usually left to the second year of a university course. The ability to integrate, should lead to the discovery of the sine curve as the solution to the harmonic equation. Other functions such as the exponential can also be discovered rather than pulled out of a hat at the right time. The need to include a constant when integrating, and to use infinitely small intervals when differentiating, can also be learned from experience.

There are many ways to integrate and differentiate numerically, but for the purposes of introducing calculus, the simplest remain the best. If interpolation of real data is attempted, students and teachers should bear in mind that fancy formulae will not make the results any more meaningful. Many of the higher order formulae are developed on the assumption that the abscissa is divided into equal intervals. These formulae frequently become unworkable when applied to real problems, especially when uncertainties are involved.

Statistics and Packages

As science is concerned with measurement, all students should understand the significance of the mean, the standard deviation and a normal distribution. If the topic of statistics is taken further, a vast array of techniques with prepackaged programmes and programme libraries will be discovered. Similar situations exist with curve fitting and numerical calculus. It is not uncommon to find postgraduate research students who have completed very comprehensive analyses of their data and yet their results remain quite common and obvious. Science teachers in general need to take pains to ensure that the mathematical techniques presented remain transparent and simple. If the teachers are also discovering new mathematical tools, they must not let their enthusiasm bewilder their classes.

Support Use of Computers

Fifteen years ago, scientific calculators were an expensive item specially chained to the desks in teaching laboratories, and they had, at best two or three memories. At the same time, all universities and some other tertiary institutions had computers specially housed in air-conditioned rooms, surrounded by operating and service staff. These computers were only accessible using punched cards and with efficient service, output became available after about three hours. Today many school children learn to use scientific calculators at the age of about 14 years. The large institutional computers remain, but computers of megabyte capacity are available for home use.

Secondary schools, in particular, were frequently not able to take advantage of the computer boom because small amounts of money were only spasmodically released for the purpose of buying computers. Unfortunately little staff retraining was offered and a few dedicated teachers managed to cope with the available systems. At the end of a few years, the software and possibly the hardware is out of date (or is thought to be out of date). Another chronic problem for secondary schools, that has strained their limited funds to buy computers, is the subsequent service of keyboards, disc drives, printers, etc. While chips rarely fail, just about every other component is at risk in the rugged school environment.

Much of the educational software developed, like the self-paced tutorial, is no more effective than a carefully planned textbook. There are now commercial programmes that offer more than a textbook, with dynamic graphics that illustrate particular points e.g., chemical titration, but this software is not suitable for the aging computers left in science classrooms.

The personal computer, with at least one (640k) floppy disc, has become a suitable computing standard for secondary education. These systems are easily available in mutually compatible clone forms and they are easily upgraded as required. When the intellectual development of secondary-school students is considered, these personal computers offer opportunities far in excess of the students realistic requirements.

The advantages of investing in a computer facility to serve several schools in an area are many. It may not be cost effective in the long term for schools to act independently. The computer facility centre would have software development staff who are aware of the content and development of the many local syllabuses (in all subjects). The centre could also have a large mainframe computer. All schools in the area can then receive updated educational software in an appropriate system code using a telephone/moden or other appropriate physical transfer of discs. Ultimately, the computer disc library will become as important as the book library. Each school will need an extra librarian who can also assist with setting up and running computers. Repairs and maintenance should be available from the central facility.

Chapter Four

RECOMMENDATIONS

RECOMMENDATIONS FOR UNESCO ACTION

In the final stages of the Workshop discussions, a list of common problems faced by participating countries was carefully compiled. Once these had been formulated, specific recommendations to UNESCO were made. There are two categories of problems in which assistance from UNESCO was sought. The first relates to those matters where direct assistance is required, or where UNESCO can approach national governments directly and advocate the requests from the Workshop. The second contains those items where UNESCO can support, and co-ordinate activities in participating countries, particularly for regional networking inputs.

Category 1A UNESCO - Governmental action

- Teachers need more time for professional improvement outside the classroom.
- The supply of science teachers should meet national quotas, or incentives are necessary to encourage science teaching as a career.
- Technological and scientific teaching cannot proceed in the absence of qualified technicians who can build and service equipment locally.
- Facilities and actual schools are needed for the designing and evaluation of new curricular projects.
- Extra-curricular activities are greatly assisted by the presence of public museums and science discovery centres.

Category 1B UNESCO Action

- Prepare a statement suggesting areas and techniques where ethical matters may be considered in the context of science and technology.
- Define the science processes that should underlie science learning and teaching, and provide guidance on a philosophical context for the learning/teaching of technological subjects.

- Provide guidance and suggestions for content, and for the integration of new topics and areas of study within existing curricula.
- Provide guidance for a holistic approach to curriculum design and teacher development.
- Set up a Resource Bank, including libraries of video tapes, computer discs, textbooks and resource notes, as well as collect and maintain examples of appropriate laboratory and demonstration equipment.
- Ensure that the science equipment offered can be manufactured and maintained by participating countries.
- Constantly revise resource materials in the light of changing content and learning/teaching practices.
- Provide schemes and assistance for the evaluation of learning and teaching.
- Provide assistance with in-service teacher training and retraining.
- UNESCO must play a leading role in co-ordinating the inter-country exchange of curriculum development, learning/teaching experiences and resources, in respect of future content.

Category 2 UNESCO - National Action

- Provide curricula updates in note form to meet local needs.
- Provide curricula amendments that identify the local flavour of contemporary science.
- Develop low cost appropriate equipment from local materials, and at the same time discourage the idea that good science needs expensive equipment.
- Provide models of practical resource kits (equipment and notes) for remote rural areas.
- Compile resource kits for teachers (rather than students), and where necessary rewrite sophisticated technical manuals so that they can assist teachers.
- Encourage the formation and growth of Science Teacher Associations as a source of professional consultants who can provide curriculum trials and peer review.

RECOMMENDATIONS FOR SPECIFIC UNESCO ACTION

1. Provide workshops in new areas of Science and Technology that will, in turn, give participants the opportunity to provide in-service courses for science teachers in their own countries, particularly in the new content areas.
2. Encourage and co-ordinate the development of resource materials in participating countries and retain samples of these materials in the Resource Bank.
3. Organize a working party to determine the basic core requirements of the traditional science so that future content can be built on a solid base.
4. Initiate a regional project on the joint elaboration of source materials which could be called UNESCO Source Materials for New Content in Science and Technology.

Suggestions from the Chinese Delegation (as an example of a national follow-up action)

For National Action

The Beijing Municipal Bureau of Education is expected to initiate a project on the promoting of science education in secondary schools. This project will be under the auspices of and sponsored by, the Chinese State Commission of Education, UNESCO and the Chinese National Commission for UNESCO. A Steering Committee will be set up to work out the plan of this project and to conduct the implementation of the plan.

On the basis of the DOSSSE Workshop, the contents and steps for implementation of the project would be as follows:

1. To convene a design workshop
   - to discuss and define the model of the science education system to be adopted;
   - to ensure what subjects of new science should be and could be introduced into the secondary schools.
2. To develop the curriculum, which will include
   - the traditional basic science courses, which should be retained;

- the new science courses which should be developed;
- the learning/teaching plan of extra-curricular and after-school activities.

3. To revise the syllabuses of the basic science courses retained, beginning with the Physics course and the Biology course for immediate attention. The requirements are:
   - to choose carefully the core unit of each course;
   - to determine the special topics (or contemporary knowledge related to each discipline) of each course and its concrete contents;
   - to determine the list of basic student activities and experiments;
   - to determine the list of indispensable demonstration experiments and video teaching-learning aids.
4. To elaborate source material for each course, including reading materials of special topics, the guide books of basic activities and experiments, audio-visual materials, and CAI software, etc.
5. To test the plan through pilot projects at several secondary schools in the Chaoyang District and other districts.

For Regional Co-operation

According to the funds raised, the co-operation at two different levels could be chosen:

1. To exchange views and share experiences through UNESCO sponsored meetings on the following:
   - models adopted
   - curricula developed
   - syllabuses revised
   - source materials produced
2. To initiate a regional project on the joint elaboration of source materials which could be called UNESCO Source Materials for New Content in Science and Technology Education

Concurrently, develop the related short term in-service teachers' training programmes which will be held within various countries.

A N N E X

Annex

LIST OF PARTICIPANTS

China (People's Rep. of)	Mr . Li Chun Professor, Branch College Beijing University Beijing
	Mr. Yang Yumin Deputy Director Beijing Education Bureau Beijing
Indonesia	Mr. Benny Karyadi Head, Curriculum of Secondary School Office of Educational and Cultural Research and Development Department of Education and Culture Jakarta
Malaysia	Dr. Sulaiman Ngah Razali Faculty of Education University of Malaya Kuala Lumpur
Mongolia	Mr. D. Dashkhuu Scientific Secretary Pedagogical Institution Ulan Bator
Philippines	Miss Victoria Cervantes Education Researcher II Science Curriculum Development Division Bureau of Secondary Education Department of Education, Culture & Sports Manila
Thailand	Dr. Chaleo Manilerd Director Institute for the Promotion of Teaching Science and Technology 924 Sukhumvit Road Bangkok

Thailand (cont'd)

Dr.(Mrs.) Wongchan Wongkaew
Assistant Professor
Department of Botany
College of Science
Kasetsart University
Bangkok

Viet Nam
(Socialist Rep. of)

Mr. Bui Thien Du
Director
International Co-operation
Ministry of Higher Education
Hanoi

RESOURCE PERSONS

Australia

Dr. Terry Freeman
School of Mathematics Physics
Computing and Electronics
Macquarie University
NSW 2109

China

Mrs. Zhao Xueshu
Associate Researcher
Central Education Research Institute
Beijing

Mr. Zheng Jun
Assistant Professor
Central Education Research Institute
Beijing

OBSERVERS

Mr. Shi Shao-Qi
Deputy Director
Chaoyang Education Bureau
Beijing

Mr. Ding Yansheng
Principal
Chaoyang Vocational Education Centre
Beijing

OBSERVERS (cont'd)

Mr. Zeng Shida
Deputy Director
Vocational Education Research Office
Central Education Research Institute
Beijing

UNESCO

Mr. F.C. Vohra
Chief Technical Adviser, NEP/86/022
UNDP
P.O. Box 107
Kathmandu
Nepal

Ratnaike, J.
Specialist in Science and Technology Education
Asian Centre of Educational Innovation for Development
UNESCO/PROAP
P.O. Box 967
Bangkok 10110
Thailand

Future Content in Science and Technology Education at Secondary Level