Learning To Learn

Key Learning Area

SCIENCE EDUCATION

Consultation Document

Hong Kong Special Administrative Region of
The People's Republic of China
Curriculum Development Council
November 2000

CONTENTS

1 INTRODUCTION

This document on the key learning area of Science Education is written in support of the consultation document ***Learning to Learn*** prepared by the Curriculum Development Council (Nov 2000) and should be read together with it. The ***Learning to Learn*** document is the outcome of the Holistic Review of the School Curriculum conducted by CDC beginning in 1999, which is done in parallel with the Education Commission's Education System Review.

2 BACKGROUND

Science Education in Hong Kong is implemented through a series of subjects at the primary and secondary levels.

Primary	Junior Secondary	Senior Secondary
• General Studies	• Science	• Biology • Human Biology • Chemistry • Physics

At the primary level, Science Education, is one of the components of the General Studies curriculum which also embraces learning elements of Personal, Social & Humanities Education and Technology Education. At the junior secondary level, the core subject Secondary 1-3 Science, consisting of topics from various science disciplines, is taught in all schools. At the senior secondary level, Biology, Human Biology, Chemistry and Physics are offered as optional subjects at Secondary 4-5 while Biology, Chemistry and Physics are further developed into Advanced Supplementary Level and Advanced Level subjects in the sixth form curriculum.

For these subjects, the intended curriculum aims to help students to:

- acquire knowledge of the empirical world;
- develop an ability to observe objectively and critically;
- develop an ability to solve problems and think scientifically;
- acquire an understanding of the relevance of science to our world and to the needs of a changing society; and
- acquire an ability to communicate using the language of science.

These aims fall in line with the broad educational aims to help students to acquire literacy and numeracy, develop thinking and reasoning abilities, acquire knowledge, and develop social, political and civic awareness as stated in the document *School Education in Hong Kong: A Statement of Aims (1993)*.

In 1999, Science Education, as one of the key learning areas of the school curriculum, has been critically examined in the process of the

holistic review of the school curriculum. The aims of science education are re-defined to align with the new aims of education for the 21st century - enabling our students to enjoy learning, enhancing their effectiveness in communication and developing their creativity and sense of commitment. Essential learning elements in Science Education are identified for the all-round development of our students.

Recommendations are made to introduce changes for improvement which will enable students to learn to learn better in science through an improved curriculum framework and improved teaching/ learning/assessment strategies. Science Education, besides contributing to the development of science capabilities in the students, will also promote the development of generic elements through a range of learning activities. Students' learning experiences in the eight key learning areas are closely linked, and learning activities if carefully planned can facilitate effective learning within limited curriculum time. Recommendations with rationale for development and exemplars for improvement are reported in the following sections.

3 RATIONALE FOR DEVELOPMENT

The problems identified in science education and highlights of the possible solutions are described below:

(1) Developing A New Science Curriculum Framework

- The science curriculum is composed of the subject syllabuses of Science, Biology / Human Biology, Chemistry and Physics at various levels. Coherence and continuity of the science curriculum need to be improved for a better coordination of the science subjects.
- The science curriculum framework for Hong Kong will be developed according to the broad aims of education in Hong Kong and up to international standards of high-achieving countries.

(2) Emphasizing Scientific Thinking

- There has been much emphasis on the content knowledge of the science subjects while high order thinking skills are neglected.
- In general, science education should enhance students' scientific thinking. It is very important that the learning of science should also contribute towards the personal development of the learners.

(3) Nurturing Interest in Science

- In some primary schools, the teaching of science is very much textbook-bound. This restricts the use of investigative and exploratory learning activities to develop students' interest in science.
- Effective teaching and learning in science should be conducted through a wide range of activities that suit the individual needs of the learners.
- It is essential that students maintain and enjoy the process of learning so that they have ownership of the learning process and thus develop into active learners in science.

(4) Developing Students to Become Active Learners in Science

- At junior secondary level, students have to face many discrete subjects and this may lead to fragmentation of knowledge. In science, many students are not able to synthesize knowledge and to learn how to apply science knowledge and skills to deal with daily-life problems.
- Students have to take an active role to connect their learning experiences in other key learning areas so that they can complete meaningful learning tasks.
- Misuse of the guided discovery approach and over-reliance on recipe-type workbooks hinder the development of students' creativity and problem solving capability.
- Students should be engaged actively in designing and conducting experiments to explore science concepts and develop science investigation skills.
- Students should also be exposed to new developments in science and develop an interest in the development of science and technology.

(5) Helping Students to Make Informed Judgements Based on Scientific Evidence

- At the senior secondary level, early specialization in subjects turns some students away from science. These students may find themselves incompetent in handling science and technology issues in their daily life.
- Students have to acquire the fundamental science knowledge and process skills involved in making informed judgements based on scientific evidence.
- It is the responsibility of science education to promote the public understanding of science and to develop students into independent learners in science.
- There is a new need for a science and technology course to cater for students not taking science subjects at the senior secondary level.

(6) Catering for Students with Strong Interest and Talent in Science

- The existing curriculum structure can only offer limited choices of science courses at the senior secondary level.

- Students with high ability or strong interest in science need more challenging learning programmes. These programmes should stretch the students' science capabilities and offer opportunities for students to develop their potential to the full.

4 PHASES OF DEVELOPMENT

4.1 Short-term (2000-2005)

Short term development builds on the strengths of teachers and schools so as to develop incremental change and interactive collaboration to support teachers and schools.

(1) Developing a New Science Curriculum Framework

- The developmental work of the curriculum framework and various science courses will be supported by try-out schemes to ensure that the proposals are built on strengths and good practices in schools. Survey and research studies will be conducted to provide systematic information for curriculum innovation in science education, such as effective use of project learning and life-wide learning in science.
- Schools wishing to try out the new approaches proposed in the science curriculum framework will be supported and their experiences will be evaluated and disseminated. Schools and teachers can promote more independent learning by infusing generic skills into the learning and teaching of science subjects, and adapt the curricula to suit the needs of students and society.
- Each school can develop its own curriculum and learning plans for the transition to using the new science curriculum framework. It is hoped that by 2005, all schools will develop a school-based curriculum in line with the open framework which is suited to the needs of their students and society.

(2) Emphasizing Scientific Thinking

- To enable students to learn independently in science, due emphasis should be placed on enhancing students' scientific thinking and strengthening their science process skills. The following is an example:

Inspiring the Inquiring Mind

Level: Junior Secondary **Curriculum: Science**
Emphasis: Developing an inquiring mind

- Teacher may employ a variety of teaching and learning strategies to promote students' inquiring minds. In the process, students are asked to propose a hypothesis for an intriguing phenomenon, such as "Why does a goldfish stay steadily in the water without either floating upwards or sinking further when it sleeps?". They will then design and conduct an experiment to test their hypothesis, and draw conclusions from experimental results for explaining the phenomenon.
- The process is related to how scientists inquire into physical phenomena and how science principles evolve from experiments.
- Through engaging in hands-on and minds-on scientific investigations, students will begin to appreciate the nature of science and develop a disposition to inquire into the world around them.
- Students' curiosity, creativity, communication skills, collaboration skills and problem solving ability are nurtured and strengthened.

- Students' learning experience beyond the classroom should also be catered for. Partnership with academic institutions and professional bodies related to the fields of science and technology (such as faculties of science in the universities and the Science Museum) will be established to help develop a range of science learning activities to promote public understanding of science and to provide authentic experiences in science.

(3) Nurturing Interest in Science

- The recommendation for the existing General Studies teachers is to conduct interesting and hands-on scientific investigation activities inside and outside classrooms to nurture students' curiosity and develop their inquiring mind. An example is shown as follows:

Science Model Making

Level: Primary Curriculum: General Studies

Emphasis: Enhancing science learning experience

- Students are introduced to simple and safe model making activities to explore simple science and technology concepts. For examples, students make curved mirrors to explore funny images or make a motor to explore how it works. These activities can either be done in class or after school.
- Teachers can either use the model-building activities as teaching resources to introduce a new topic, as consolidation exercises after a topic, or as starting material for scientific investigation.
- The science model making activity provides opportunities for students to explore simple science concepts in specific topics of General Studies. Students gain precious hands-on experience in science and technology through manageable activities.
- Through these activities, students' curiosity, creativity and investigatory spirit are cultivated. Students' communication, collaboration and study skills are also developed.

- A new framework for the General Studies curriculum to enhance science and technology learning experiences will be developed. This will serve as a reference for teachers to design their school-based curriculum.

(4) Developing Students to Become Active Learners in Science

- The revised Secondary 1-3 Science curriculum for implementation in September 2000 has already included the main characteristics of the new science curriculum framework, such as strengthening science process skills, integrating science education strands and including both core and extension topics.
- Schools may design their school-based curriculum based on the core topics and spare curriculum time for a wide range of learning activities. In particular, the use of problem-solving projects in science and technology at junior secondary level is recommended. This will help improve students' understanding and mastery of the processes of science and skills in solving problems. All these will contribute towards the development of active learners in science.

(5) Helping Students to Make Informed Judgements Based on Scientific Evidence

- The existing science syllabuses, Biology, Chemistry and Physics will be revised for implementation in September 2003. The revision will emphasize the development of scientific thinking, problem solving ability and independent learning.
- For students not taking these science subjects, a new course, Integrated Science and Technology, will be introduced for empowering them to cope with a dynamically changing environment and to make informed judgements in a technological society. The new course will include modules of multi-discipline Science and Technology topics such as environmental science and health science. The following is an example showing informed judgement in science education:

Informed Decisions Based on Scientific Evidence

Level: Senior Secondary Curriculum: Biology/Chemistry/Physics
Emphasis: Making informed judgements

- These are activities to promote the development of rational decision-making skills applicable to major science-related issues of personal and public concern. Students will be asked to collect evidence, to judge the reliability and validity of these data, to resolve ambiguities, to balance the advantages and drawbacks of alternative solutions, and to project the likely consequences of a particular choice.
- Examples of topics for such activities include "Genetically Modified Food", "Gender Selection", "Cleaner Fuels", "Nuclear Energy", "EM Radiation of Mobile Phones", "Effects of High Voltage Transmission Stations on Health" etc., which encompass more than one subject discipline.
- The format of these activities will be in the form of a forum, whereby the teacher will act as the chairperson to introduce the issue and provide background information. The teacher plays the role of a facilitator to guide students to look for relevant information, to provide guiding questions, to encourage students to voice their opinions, and to help clarification of values.
- Students will develop their various generic skills in the search for information, in analyzing problems, and in their debates/ presentation.

(6) Catering for Students with Strong Interest and Talent in Science

- A variety of learning activities in the form of science competitions, experimental projects, independent study projects and issue-based learning projects are essential to develop students' capabilities in science and technology. These activities may be conducted in the form of school-based programmes or in collaboration with tertiary institutions, professional bodies or the commercial sector.

For successful realization of the recommendations in science education, the following types of teacher development programmes for empowering science teachers at various levels are needed:

- seminars and workshops for teachers to share experiences on good practices in conducting hands-on and exploratory activities;
- courses with practical sessions to update teachers with new developments in science and technology; and
- web-based teacher development programmes to upgrade teachers' knowledge of science.

Teachers will also need support from various sources:

- The Education Department will support schools through the Science Section, school-based curriculum teams and regional education offices.
- CDC will build up a resource repository on the Internet to support teachers in adapting to the proposed changes in the curriculum reform.
- Teachers will also need the assistance of laboratory technicians in scientific investigation. In this respect, the laboratory technicians may also need training to familiarize them with the new requirements of the science curriculum framework.

4.2 Medium-term (2005-2010)

With tertiary-wide support and experience gained through various sources, schools should develop their curriculum to enable students to attain the learning targets in science and also targets in generic

elements. The science curriculum framework, which will be revised with the targets validated and calibrated, will serve as a reference for schools to develop and provide learning programmes for their students.

For the primary students, besides learning science in the traditional mode of teaching in the classrooms, it is expected that teachers can spend an adequate amount of time conducting hands-on investigative activities to nurture students' curiosity, to construct their knowledge in science and to develop basic science process skills. Students will also need a wide range of science learning activities which can be provided by the museums and resource-based learning centres.

At the junior secondary level, effective learning in science can be done through connecting students' learning in science and technology. Through project learning and life-wide learning, students will build a solid foundation in science and technology. They will also develop the necessary process skills for life-long learning.

At the senior secondary level, students should have opportunities to undergo a broad and balanced curriculum through a process of academic study, life-wide learning and service learning. Students will acquire their necessary science knowledge and process skills for personal development and for them to contribute as modern citizens towards a scientific and technological world.

4.3 Long-term (2010+)

The long-term goal of science education is to help the students to develop interest in science and to master the essential science knowledge and skills to become life-long learners in science and technology. Science education should also help students learn how to deal with the pace of scientific and technological development and prepare them for a world we cannot predict.

5 THE FRAMEWORK

5.1 Overall Aims

Science education aims for students to:

- develop curiosity and interest in science;
- develop the ability to inquire and solve problems;
- acquire the basic scientific knowledge and concepts for living in and contributing to a scientific and technological world;
- recognize the usefulness and limitations of science and the interactions between science, technology and society and to develop an attitude of responsible citizenship, including respect for the environment and commitment to the wise use of resources;
- be acquainted with the language of science and be equipped with the skills for communicating ideas in science related contexts;
- appreciate and understand the evolutionary nature of scientific knowledge;
- attain personal growth through studying science; and
- be prepared for further studies or enter careers in science and technological areas.

5.2 Learning Targets

Through various stages of schooling, students will acquire the necessary knowledge, skills and attitudes in science education. The learning targets of science education at various stages of schooling are described below.

On completion of the primary level, students should:

- show curiosity and interest in science and ask questions related to Nature and their environment;
- use focused exploration and investigation to acquire scientific understanding and skills;
- relate their understanding of science to domestic and environmental contexts;
- relate their understanding of science to their personal health and develop sensitivity to safety issues in everyday life and take action to control these risks;
- use their knowledge and understanding of science to explain and interpret a range of familiar phenomena; and
- consider how to treat living things and the environment with care and sensitivity.

On completion of the junior secondary level, students should:

- acquire basic scientific knowledge and concepts for living in and contributing to a scientific and technological world;
- develop the ability to define problems, design experiments to find solutions, carry out practical work and interpret the results;
- apply their understanding of science to technological applications, social issues, and their daily experiences;
- recognize the usefulness and limitations of science and the evolutionary nature of scientific knowledge;
- relate their understanding of science to their personal health and cultivate an awareness of safety issues in everyday life and take proper action to control these risks; and
- consider the effects of human activities on the environment and act sensibly in conserving the environment.

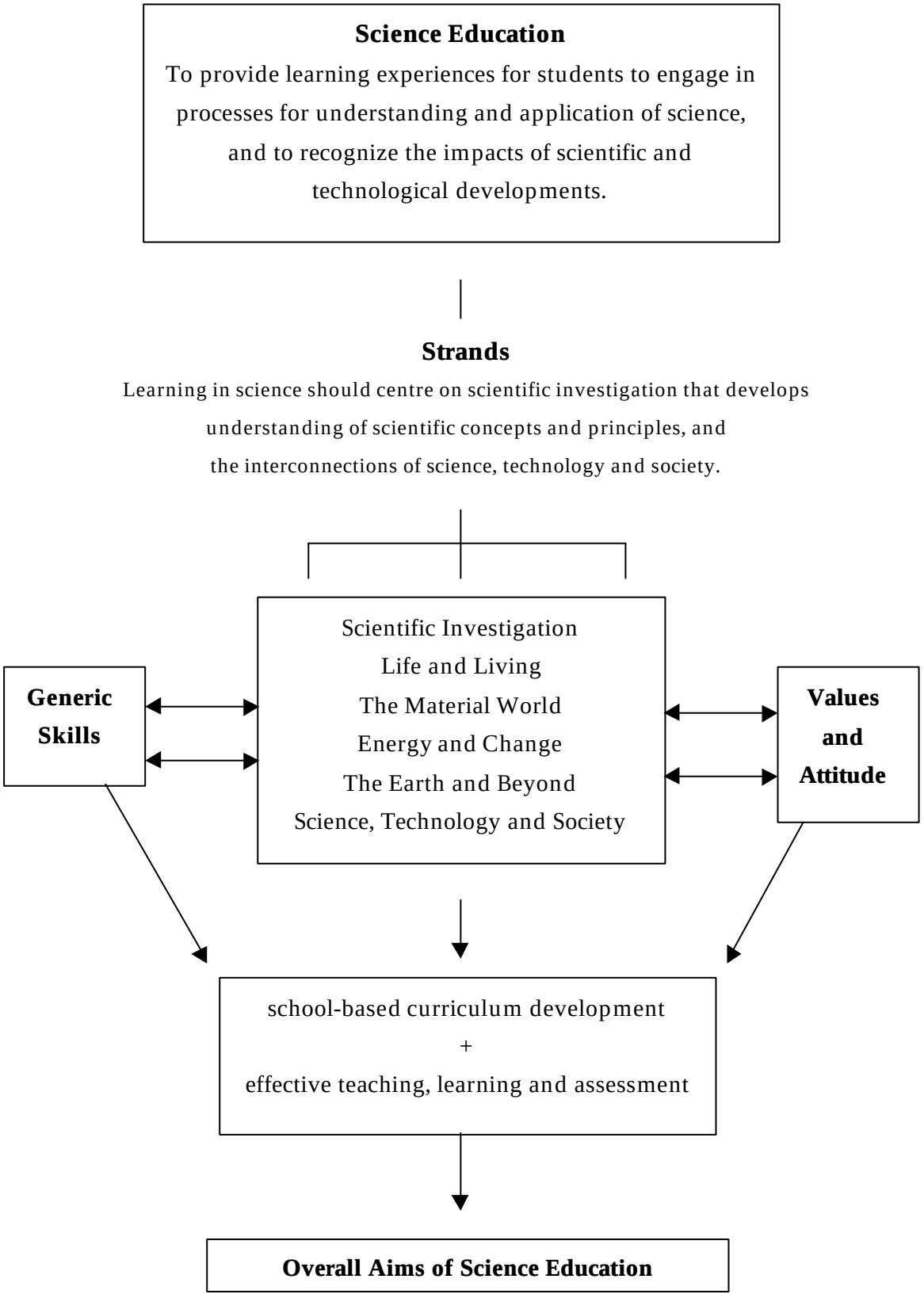
On completion of the senior secondary level, all students should:

- have a fundamental understanding of essential scientific knowledge and concepts for contributing towards a scientific and technological world;
- have the ability to solve problems by employing scientific approaches and methods;
- make informed judgements and decisions based on scientific evidence;
- be able to comprehend issues related to the nature and development of science and technology;
- make sensible judgements on their personal health and take responsible actions in safety issues; and
- acknowledge the effects of human activities on the environment and act responsibly in conserving the environment.

Detailed learning targets, including those for students who opt for specialized science courses at senior secondary level, at various stages of schooling are outlined in Appendix 1.

5.3 Components of the Framework

Diagrammatic Representation of the Science Education Framework

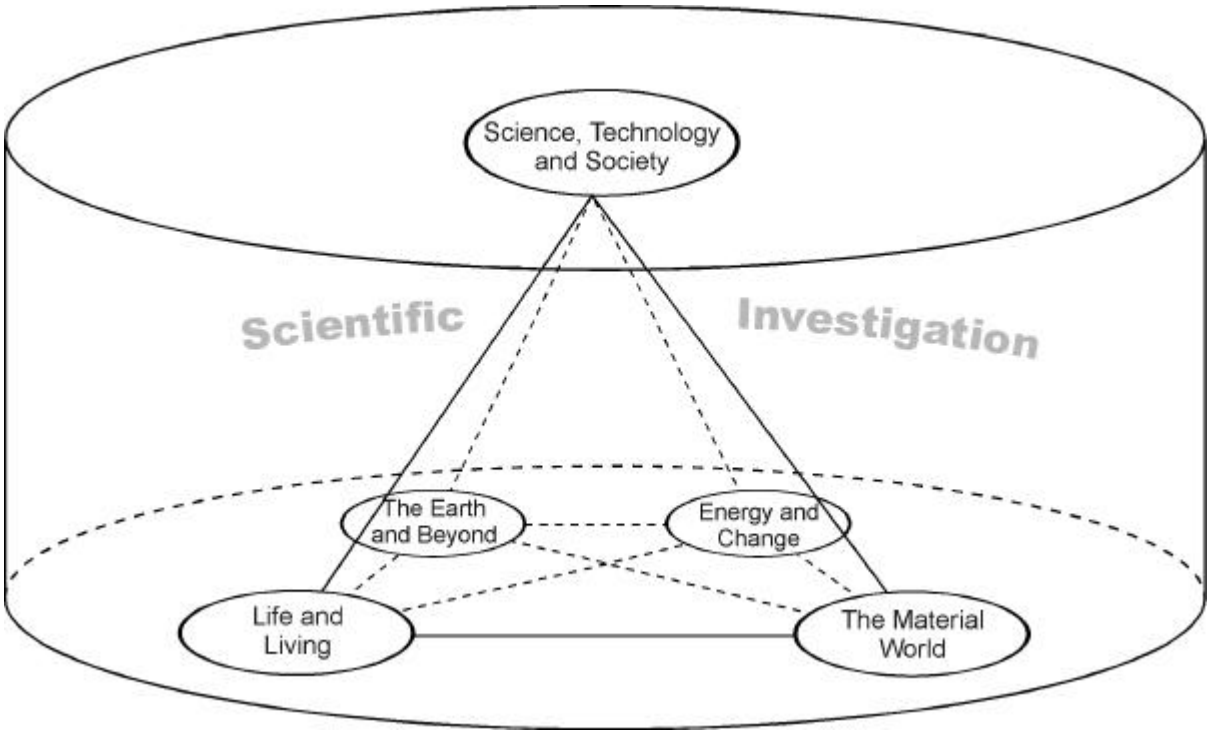


5.3.1 Strands

The arrangement of major learning elements in science as strands in the science curriculum is needed for the purpose of curriculum planning and organization. Essential learning experiences for achieving the aims of science education are organized into six strands:

- **Scientific Investigation** – to develop science process skills and understanding of the nature of science
- **Life and Living** – to develop understanding of scientific concepts and principles related to the living world
- **The Material World** – to develop understanding of scientific concepts and principles related to the material world
- **Energy and Change** – to develop understanding of scientific concepts and principles related to physical processes
- **The Earth and Beyond** – to develop understanding of scientific concepts and principles related to the Earth, the Space and the Universe
- **Science, Technology and Society** – to develop understanding of how science and technology affect society

Learning in science should centre on **Scientific Investigation** that helps developing students' understanding of scientific concepts and principles of **Life and Living, The Material World, Energy and Change** and **The Earth and Beyond**, and further develop students' understanding of the interconnections of **Science, Technology and Society**. The six strands are inter-related and can be represented graphically by the following diagram:



5.3.2 Generic Skills

As life-long learners, our students need certain skills that are essential in order to handle ever-renewing knowledge. These generic skills, which are sometimes called by other categorical names such as key skills, cross-curricular skills or transferable skills, are to be developed throughout all stages of schooling and across the key learning areas.

The following nine types of generic skills are considered essential for one's success in life-long learning and personal development:

- collaboration skills
- communication skills
- creativity
- critical thinking skills
- information technology skills
- numeracy skills
- problem solving skills

- self-management skills
- study skills

In science education, students should develop the intellectual and practical skills which allow them to explore and investigate the world of science. Students must learn these skills and be able to transfer these skills from one learning context to another, be it within the science arena or not. Transferability of these skills, and eventually leading to the acquisition of new knowledge, will help students continue to learn.

Appendix 2 illustrates how the learning experiences in science can foster the development of generic skills.

5.3.3 Values and Attitudes

The science curriculum sees the essential elements of developing learning experience in science as being "to investigate and explore, to communicate, to relate science to everyday life and to make informed decisions". Science is a unique form of knowledge in which, through the process of scientific enquiry, learners will bring the scientific method to the processes of problem solving, decision making and evaluation of evidence. In this sense, students' inquiring mind is important if they are to engage purposefully in scientific activity. The values and attitudes which need to be developed to produce effective scientific ways of thinking and working include:

- curiosity
- perseverance
- critical reflection
- open-mindedness
- appropriately valuing the suggestions of others
- sensitivity to the living and non-living environments
- willingness to tolerate uncertainty
- respect for evidence
- creativity and inventiveness

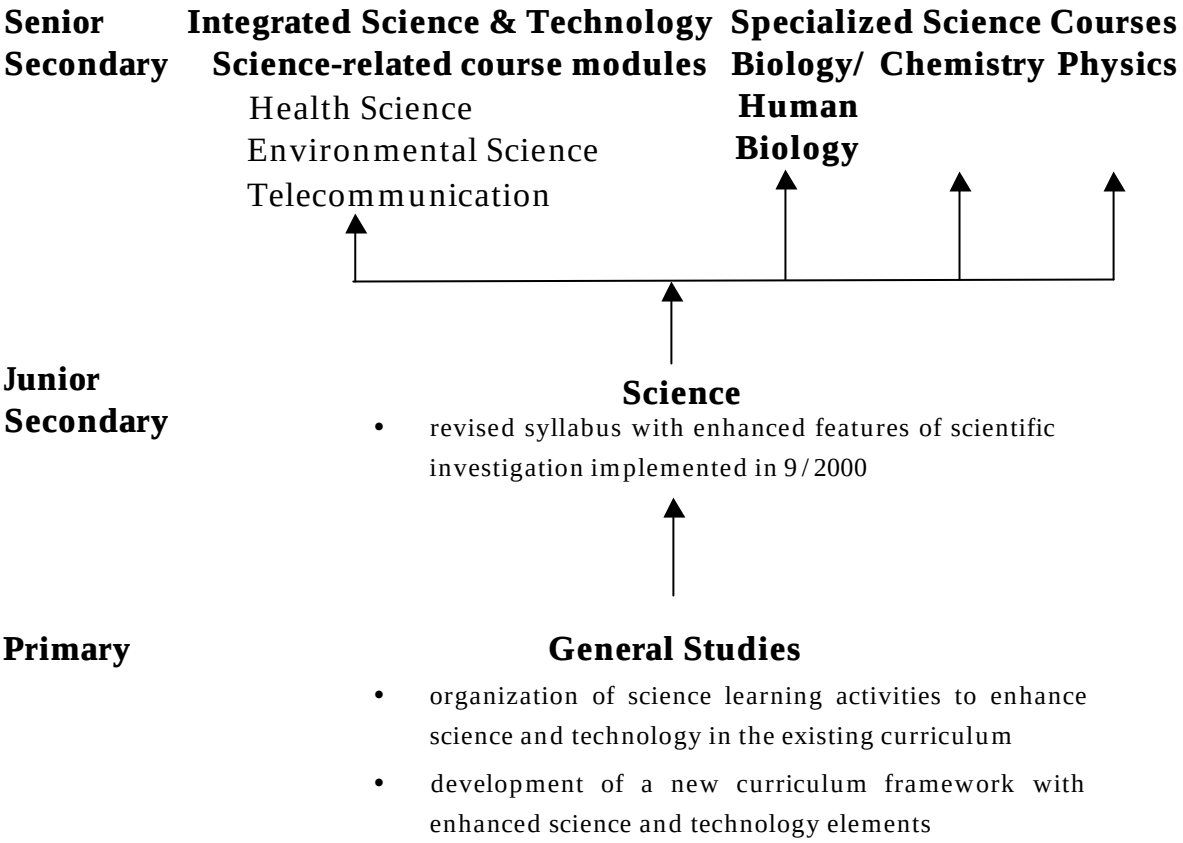
Appendix 3 contains exemplars illustrating the development of values and attitudes through science education.

5.4 Modes of Curriculum Planning

Changes in the organization of the science curriculum in schools for promoting science education in Hong Kong are proposed. The principles employed in designing the new science curriculum are:

- to enhance students' scientific thinking and strengthen their investigative and problem solving skills;
- to enhance science and technology learning experiences in the primary school curriculum in order to nurture students' curiosity and develop their inquiring mind;
- to improve the coordination of fundamental science and technology courses at junior secondary level to improve the effectiveness of teaching and learning in science and technology;
- to develop among senior secondary students a solid foundation in science and technology for empowering them to cope with a dynamically changing environment and to make informed judgements in a technological society; and
- to have science disciplines as optional courses to enable senior secondary students to specialize in further study and to prepare them for future workplace.

Proposed science courses for primary and secondary schools are as follows:



In the short term, new approaches are explored in re-designing the General Studies curriculum, an outline of which is contained in Appendix 4.

The revised Secondary 1-3 Science Syllabus with enhanced features of scientific investigation is to be implemented in September 2000. The existing science syllabuses, Biology, Chemistry and Physics at Secondary 4-5 level, will be revised for implementation in September 2003 to reflect the changes in the new science curriculum framework.

For the proposed Integrated Science and Technology course at Secondary 4-5 level, an outline is contained in Appendix 5.

5.5 Teaching, Learning and Assessment

To learn effectively, students must take on an active role in science investigation. The following are ways to involve the learners in science learning processes:

- Students must initiate their own learning and take responsibility for their own learning. Learning science involves enquiring into the environment; the problem to be investigated should come from within the students, from their need to know or to find a solution. Students need to shape the questions themselves so that the investigations become their task. This way they feel in control and fully involved in their own learning.

- Students must take part in making decisions and solving problems. When students are allowed to make decisions towards the solution of a problem they will begin to own the problem for themselves.

- Students must learn to transfer skills and learning from one context to other different contexts in science. Transferability of the process of investigation and acquisition of new knowledge will help students to continue to learn.

- Students must participate in organizing themselves and organizing others. Active learning in science requires students to work both independently or within a group. They will use a range of study skills, and select the most appropriate resources (e.g. the suitable piece of apparatus) and information and the means of gaining access to them.

- Students must be able to display their understanding and competence in a number of different ways. Students are expected to select the most appropriate means of reporting an experiment or project to the audience, to present their data (e.g. which graph or table to draw), to communicate

and to explain their ideas and understanding so that others can appreciate them.

- Students need to be engaged in self- and peer-evaluation during the process of learning. Active learning requires that students develop their own criteria of assessment, evaluate their own progress and recognize their own competence and weaknesses and assist in the evaluation of others' progress.

- Students must feel good about themselves as learners. Active learners believe in themselves and grow in enthusiasm for what they are doing. It is hoped that success breeds confidence and, in turn confidence breeds positive feelings and motivation.

Assessment in science plays an important role for both the teachers and the learners. In order to bring about improvement in teaching and learning, it is essential that assessment be aligned to the process of teaching and learning. Authentic assessment needs to be introduced to serve as a diagnostic tool to help improve students' learning in science. While due emphasis is given to the development of scientific investigative skills, assessment based on performance standards designed according to the learning targets is crucial to the success of the proposed improvement measures in science education. The performance standards should be developed through systematic research and comparison studies. Assessment mechanisms and instruments will need to be developed and evaluated through tryouts in a sample of schools. Extensive professional development programmes will be needed to equip the science teachers with the essential knowledge and skills to handle assessment effectively and with confidence. Teachers should also be trained to use the feedback information generated from assessment activities for improvement purposes. The following is an example showing assessment for improving students' learning in science:

Assessing Science Practical Work

Level: Junior Secondary Curriculum: Science
Emphasis: Assessment for improving students' learning in science

- Practical work is the vehicle for hands-on interaction with science knowledge. Proper mastery of practical skills enhances safe and efficient exploration and investigation of phenomena around us.
- Practical assessments that align with the learning objectives are part of the feedback mechanisms in science teaching and learning. For example, asking students to heat a beaker of water to 80^{o}C with a Bunsen burner or design and draw the circuit diagram for an alarm system. Through the assessment, teachers can gain information about students' competency in manipulating apparatus and instruments correctly and safely as well as their understanding of the underlying scientific principles.
- The assessment also helps develop and strengthen students' experimental and manipulation skills, consolidate their scientific knowledge and identify their problems with practical work.
- Well-designed practical assessment provides opportunities for students to develop problem solving and thinking skills. Students' perseverance, confidence, creativity and participatory attitudes are also cultivated.

5.6 School-based Curriculum Development

Schools can develop their own curriculum and learning plans in line with the new science curriculum framework to suit the needs of students and society. The revised Secondary1-3 Science curriculum (implemented in September 2000) is organized into core and extension parts to allow for flexibility in the organization of the school-based science curriculum. The core represents the basic components of science that all students should learn. The extension constitutes additional learning for specific groups of students. The level of attainment for each topic within the extension will vary from school to school and within a school from class to class. Teachers can design a school-based curriculum adapted from the core and

extension parts of the revised curriculum to suit the needs, interests and abilities of their students.

In adopting a school-based curriculum, there will be more room for a variety of activities to promote learning in science. For example, teachers may:

- arrange visits to the Science Museum for introducing specific science topics in the General Studies curriculum so as to arouse students' interest in science and enhance science learning through life-wide learning;
- conduct fun science projects for junior secondary students so as to involve students actively in learning activities for solving science and technology problems; and
- encourage students to take part in science competitions to stretch their capabilities in science.

Furthermore, teachers may:

- re-design the school-based General Studies curriculum with the assistance of curriculum consultants to enhance the science and technology elements through learning activities in resource-based learning centres, such as laboratories in secondary schools or institutes;
- inspire students' inquiring mind in scientific investigation which requires students to make hypotheses, design and carry out experiments, collect and analyze data, make judgements and report results and conclusions; and
- act as mentors and advisors in science projects for senior secondary students to develop students' scientific investigative skills and their communication, collaboration, IT and critical thinking skills.

5.7 Life-wide Learning

Besides the traditional classrooms and laboratories, students can

learn science in many contexts and situations. To bring about improvements in teaching and learning, schools may seek support and assistance from various government departments, tertiary institutes, professional bodies, resource-based centres, voluntary organizations and peer schools. A wide range of learning programmes can be provided through community-wide support. These learning programmes will provide learning experiences in the form of popular science lectures, issue-based learning, debates and forums, exposition, museum visits, invention activities, science competitions, science projects, science exhibitions, field trips, laboratory research and experiments.

A description of the exemplars for improving the teaching and learning of science through school-based curriculum development and/or life-wide learning can be found in the website – http://www.cdc.org.hk/science. The exemplars include:

Primary Level

(1) Science Model Making
(2) Science Project Competition
(3) Science Summer Camp
(4) Visits to the Ocean Park and Science Museum
(5) Lessons for Field Experience

Junior Secondary Level

(6) Flexible Curriculum with Core and Extension
(7) Inspiring the Inquiring Mind
(8) Science and Technology Projects
(9) Fun Science Competition
(10) Visit to the Space Museum and Health InfoWorld
(11) Roving Science Exhibition
(12) Assessing Science Practical Work

Senior Secondary Level

(13) Project Learning: Chemistry Olympiad

(14) Informed Decisions Based on Scientific Evidence
(15) Joint School Science Exhibition
(16) Field Studies Courses
(17) Visit to the Hong Kong Observatory
(18) The Science Iron-man Summer Programme
(19) Summer Biology Seminar Series and Research Camp
(20) Data Logging Experiments
(21) Microscale Chemistry

5.8 Connections with Other Key Learning Areas

It is very important that teachers can help students to connect their learning experiences in science and with those in other key learning areas. This will facilitate effective learning with limited curriculum time. Some of the examples are:

Science and Language Education

- reading of science fiction, stories of scientific discovery and scientists for fostering interest in science

Science and Mathematics

- data handling for the investigation and interpretation of quantitative information

Science and Personal, Social & Humanities Education

- cross-curricular studies such as health education, sex education and environmental education

Science and Arts Education

- appreciation of the beauty of natural phenomena

Science and Physical Education

- cross-curricular studies, such as health education

Science and Technology Education

- application of scientific principles in design and problem solving processes
  (It is widely accepted that learning experiences in science and technology are intertwined. The diagram at Appendix 6 illustrates their relationship.)

Exemplars of connecting Science Education with other key learning areas can be found in the website – http://www.cdc.org.hk/science

6 CONCLUSION

In this document we have set out our vision of science education for the 21st century. We recognize, however, that this is a long-term goal that will have to be approached gradually and with the involvement of teachers. To prepare teachers for the new development, the following measures will be taken:

- finalization of the science curriculum framework that serves as a reference for teachers to design a school-based curriculum;
- conducting research and development projects to identify good practices and produce resource materials for teaching and learning;
- dissemination of good practices and resource materials through sharing among teacher networks, Internet and series of teacher development programmes; and
- CDC to build up a resource repository on the Internet to support teachers in adapting to the proposed changes in the curriculum reform

With the concerted efforts of teachers, school heads, science academics, science educators and curriculum developers, improvements in the quality of teaching and learning are to be anticipated.

You are welcome to send your views to the Curriculum Development Council Secretariat by post, by fax or by e-mail on or before 15 February 2001.

Address: Curriculum Development Council Secretariat
Room 1329, Wu Chung House
213 Queen's Road East
Wan Chai
Hong Kong
Fax Number: 2573 5299 / 2575 4318
E-mail Address: cdchk@ed.gov.hk

Appendix 1

Learning Targets at Various Stages of Schooling

Appendix 1

Learning Targets at Key Stage 1 (Primary 1-3)

Scientific Investigation

- To show curiosity and interest in science.
- To demonstrate interest in exploring their environment and solving simple problems with science.
- To plan and conduct simple investigations in familiar situations.
- To record and discuss observations and suggest simple interpretations.

Life and Living

- To recognize the features of living things through observing and interacting with Nature.
- To develop healthy living habits.
- To appreciate the characteristics of living things.
- To develop a general understanding of life processes.
- To work with peers in the care of living things.

The Material World

- To identify daily materials and their uses.
- To list the ways materials are used for different purposes.
- To identify characteristics and changes in materials using the senses.
- To be committed to environmentally friendly practices.

Energy and Change

- To describe ways energy is used in daily life.
- To identify sources of energy in daily life.
- To recognize some of the properties of heat and movement.
- To be aware of safety issues in the use of energy in daily life.

The Earth and Beyond

- To identify and describe the basic patterns and objects in the sky.
- To identify simple features of weather changes.
- To recognize the Earth as a wealth of resources.

Science, Technology and Society

- To appreciate some of the ways scientific and technological advancements have affected our life.
- To show concern for the environment and make wise use of natural resources.
- To recognize some of the ways modernization and the information era have affected us.

Appendix 1

Learning Targets at Key Stage 2 (Primary 4-6)

Scientific Investigation

- To show curiosity and inquisitiveness in science.
- To demonstrate interest in exploring their environment and solving simple problems with science.
- To plan and conduct simple investigations in familiar situations.
- To record and discuss observations and suggest simple interpretations.

Life and Living

- To appreciate the existence of a variety of living things.
- To identify personal needs and the needs of other familiar living things.
- To identify observable personal features and be aware of the functions of different parts of the human body as the basis of self-care.
- To identify features of animals and plants that change over time.
- To recognize the interdependence of living things and their environment.

The Material World

- To suggest how materials are used and their related consequences.
- To distinguish between changes that cannot be easily reversed and those that can.
- To illustrate ways natural materials are processed and the consequences on humans and the environment.
- To be committed to the wise use of natural resources and the conservation of the environment.

Energy and Change

- To recognize some of the patterns and phenomena related to light, sound, electricity and movement.
- To report on patterns of energy use in the home, school and other workplaces.
- To identify safety measures associated with the use of different forms of energy.
- To be committed to the wise use and conservation of energy in daily life.
- To design and make models enabling the efficient transfer of energy.

The Earth and Beyond

- To list ways that the local environment influences our daily life.
- To identify features of the day and night sky and relate them to patterns of our daily life.
- To identify and describe weather and seasonal changes and their effects.

- To illustrate patterns of changes observable on the Earth caused by the sun, the Earth and the moon.
- To appreciate that people have always marveled at the vast universe and their efforts in trying to learn more about it.

Science, Technology and Society

- To appreciate some of the ways scientific and technological advancements have affected our life.
- To show concern for the environment and make wise use of natural resources.
- To appreciate that the study of science is partly for creating meaning in our world and partly to improve our quality of life.
- To discuss and recognize some of the ways modernization and the information era have affected us.

Appendix 1

Learning Targets at Key Stage 3 (Secondary 1-3)

Scientific Investigation

- To carry out controlled experiments for solving problems.
- To plan and conduct investigations in laboratories.
- To evaluate the fairness of tests and argue conclusions based on findings.

Life and Living

- To recognize the variety of life and to understand the classification system.
- To understand the body organization of living things down to cellular level.
- To understand some life processes.
- To develop a general understanding of the human reproductive cycle and its relation to sex education.
- To understand the effects of diet, exercise and drugs on body health.

The Material World

- To understand physical and chemical properties.
- To understand how materials are used and their related consequences.
- To investigate some chemical changes and the substances involved.

Energy and Change

- To compare energy options available for particular purposes in the community.
- To identify processes of energy transfer and conditions that affect them.
- To identify forms and transformations of energy in sequences of interactions.
- To relate observed changes in an energy receiver to the quantity of energy transferred.

The Earth and Beyond

- To understand that the earth's crust is a useful source of minerals.
- To describe the effects of gravity and frictional forces on the motion of an object on earth.
- To understand the basic concepts and conditions for space travel.

Science, Technology and Society

- To understand the use of materials and their impacts on the environment.
- To recognize the effects of human activities on the environment.
- To act responsibly in conserving the environment.
- To recognize the limitations of scientific knowledge and technology.

Appendix 1

Learning Targets at Key Stage 4 (Senior Secondary)

Scientific Investigation

- To select and follow appropriate ways for investigations with specific purposes.
- To plan and conduct science experiments for solving problems.
- To collect information and draw conclusions for decision-making.

Life and Living

- To develop a basic understanding of the essential life processes.
- To recognize the effects of genes and inheritance on living things.
- To evaluate the impacts of global environmental issues on the quality of life.
- To be committed to a healthy life.

The Material World

- To understand the relation of the uses of domestic chemicals and their properties.
- To examine classes of chemical reactions and predict their applications.
- To investigate the processing of raw materials.
- To evaluate the use of materials.

Energy and Change

- To describe systems whose purpose is to transfer energy efficiently.
- To explain the principles of energy input-output devices.
- To apply ideas of energy conservation and efficiency to sequences of interactions.
- To analyze and compare situations to demonstrate the conservation of energy.

The Earth and Beyond

- To know ways in which technology has increased our understanding of the universe.
- To recognize natural changes in the environment, such as seasonal changes, geological changes and natural disasters.
- To describe the impact of human activities on the environment, such as the construction of roads and buildings, and the extraction of natural resources.

Science, Technology and Society

- To evaluate the impact of science applications on human activities.
- To analyze ways that scientific and technological developments influence society.
- To identify the pros and cons of scientific applications for making informed decisions.

- To develop an awareness of the need to evaluate environmental issues from a variety of perspectives.
- To demonstrate responsibility for the local and global environments.

Appendix 1

Learning Targets at Key Stage 4 (Specialized) (Senior Secondary)

Scientific Investigation

- To select instruments and techniques in science experiments.
- To collect quantitative and qualitative information with accuracy and generate reliable results.
- To analyze and assess findings and draw conclusions for solving problems.

Life and Living

- To understand the structures and life processes in cells.
- To understand and explain the underlying mechanisms of life processes.
- To understand and explain genetic control and inheritance.
- To understand and explain the principles of regulation and control in living things.
- To describe the reproductive cycles of flowering plants and human beings.
- To describe and explain the interactions of living things in ecosystems.
- To understand the underlying principles affecting health.

The Material World

- To assess the effectiveness of materials used for particular purposes.
- To use simple models of atoms to explain chemical reactions.
- To use the properties of reactants to predict the products of chemical reactions.
- To understand fundamental chemical principles.
- To investigate the industrial and everyday applications of chemical reactions.

Energy and Change

- To report on ways that scientific research is addressing questions of energy production and use.
- To use scientific knowledge to make recommendations on the utilization of energy.
- To investigate various models used to explain energy transfer.
- To apply principles of energy transfer, conservation and efficiency to sequences of interaction.

The Earth and Beyond

- To understand the gravitational forces which determine the movements of planets, moons and satellites.
- To understand the principles of instruments for observing objects in the sky.

- To describe the structure of the Earth and the composition of the atmosphere.
- To understand that a variety of useful substances can be made from rocks and minerals.

Science, Technology and Society

- To reflect on the position of human beings in the living world.
- To take responsibility in using science in various settings.
- To value the role of science in monitoring the environment and in understanding and working to resolve environmental problems.
- To understand the interconnections of science, technology and society in the development of a sustainable society.

Appendix 2

Generic Skills and Science Education

Appendix 2

Generic Skills in the School Curriculum

- **Collaboration Skills**

  Problem solving, planning and making decisions in a small group require the necessary collaboration skills, namely the skills of listening, appreciation, communication, negotiation, making compromises, asserting leadership, making judgement, as well as influencing and motivating others. Learners with these skills will be able to effectively engage in tasks and teamwork as well as working with others. Ultimately, learners will be able to form relationships that are mutually beneficial.

- **Communication Skills**

  Communication is a dynamic and ongoing process in which two or more people interact in order to achieve a desired outcome or goal. In learning to communicate effectively, learners should learn to speak, listen, read and write effectively. They should learn to select the most appropriate means to convey a message in accordance with the purpose and context of the communication. They should use accurate and relevant information and organize it systematically and coherently for their audience. They should also evaluate the effectiveness of their communication and identify areas of improvement for action.

- **Creativity**

  A brief description: Creativity is an important but elusive concept. It has been defined in a variety of ways. Some people define it as an ability to produce original ideas and solve problems, others see it as a process, and yet others take it as certain personal qualities. In fact, creativity is a complex and multifaceted construct. Within the individual, creative behaviour is the result of a complex of cognitive skills/abilities, personality factors, motivation, strategies, and metacognitive skills. A person's creative performance may not correspond to his/her developmental stages.

  General Principles: Although the demanding process of teaching for creativity is hard to make routine, some principles apply in general. To develop students' creativity, we ask them to go beyond the given information, allow them time to think, strengthen their creative abilities, reward their creative efforts, value their creative attributes, teach them creative thinking techniques and the Creative Problem Solving model, and create a climate conducive to creativity. These principles can be employed in all key learning areas (KLAs).

- **Critical Thinking Skills**
  Critical Thinking is drawing out meaning from given data or statements. It is concerned with the accuracy of given statements. It aims at generating and evaluating arguments. Critical thinking is the questioning and inquiry we engage in to judge what to and what not to believe.

- **Information Technology Skills**
  IT skills are the ability to use IT to seek, absorb, analyze, manage and present information critically and intelligently. In addition, IT will motivate and empower our learners to learn at their own pace and help them develop habits of self-learning, which will benefit them for life.

- **Numeracy Skills**
  Numeracy skills include the ability to perform basic computations, to use basic mathematical concepts in practical situations, to make reasonable estimates, to understand graphs, charts and numerical concepts in languages, to manage data, to handle money and do stock inventories.

- **Problem Solving Skills**
  Problem solving involves using thinking skills to resolve a difficulty. It assembles facts about the problem and determines the best course of action.

- **Self Management Skills**
  Self-management skills are essential for the building up of self-esteem and the accomplishment of goals. Learners who have mastered self-management skills understand their own feelings and preserve emotional stability. They are positive and proactive towards work. They set appropriate goals, make plans and initiate actions to achieve them. They manage time, money and other resources well. They are able to handle stress and tolerate ambiguities.

- **Study Skills**
  Study skills are the basic techniques that help to improve the effectiveness and efficiency of learning. They are crucial to the development of the basic learning habits, abilities and attitudes of the learners that form the essential foundation for lifelong learning.

Appendix 2

Development of Generic Skills through Science Education

The following points can illustrate how learning experiences in science can foster the development of generic elements and skills by engaging students in investigative activities such as project work or experiments:

- Students have to work independently or within a group. They have to organize themselves and organize others, and to participate actively in information searching, planning, choosing appropriate instruments, assessing the validity and appropriateness of information etc. Thus they will demonstrate collaboration skills, problem-solving skills, critical thinking skills, communication skills etc.

- Students, in order to display their understanding and the mastery of concepts or the whole process of problem-solving, are expected to select appropriate means of reporting an experiment or project to the audience. They have to present their data, to apply mathematical skills to analyze the data in some cases, to draw conclusions, to communicate and to explain their ideas and findings to others. This involves a lot of skills like numeracy, IT, communication, and may involve a lot of creativity from the design to reporting.

- The new scientific literacy requires increasing ability and willingness to reflect on the positive and negative sides of science, the fallible and contingent character of science and scientists, and the application of science in contexts. Such reflections allow a scientifically literate citizen to critically evaluate science and science authority. By reading, discussing, and even role-playing scientific controversies, students see situated, contingent and contextual features of scientific knowledge. When confronted with issues, students will then be able to make judgements and draw up their conclusions. In the reporting process, students have to be self-critical as well as to accept evaluation from others - and to be critical in evaluating others. Thus critical thinking skills are nurtured throughout such processes of active learning in science.

More exemplars to illustrate the development of generic skills through science education can be found in the website - http://www.cdc.org.hk/science.

Appendix 3

Values and Attitudes in Science Education

Appendix 3

Values and Attitudes in the School Curriculum

The following is an outline of the values and attitudes in the school curriculum:

Personal		Social	
Core Values	**Sustaining Values**	**Core Values**	**Sustaining Values**
- sanctity of life - truth - aesthetics - honesty - human dignity - rationality - creativity - courage - liberty - affectivity - individuality	- self-esteem - self-reflection - self-discipline - self-cultivation - principled morality - self-determination - openness - independence - enterprise - integrity - simplicity - sensitivity - modesty - perseverance	- equality - kindness - benevolence - love - freedom - common good - mutuality - justice - trust - interdependence - sustainability - betterment of human kind	- plurality - due process of law - democracy - freedom and liberty - common will - patriotism - tolerance - equal opportunities - culture and civilization heritage - human rights and responsibilities - rationality - sense of belonging - solidarity

Attitudes
- optimistic - participatory - critical - creative - appreciative - empathetic - caring and concern - positive -confident - cooperative - responsible - adaptable to changes - open-minded - with a respect for ・ self ・ life ・ quality and excellence ・ evidence ・ fair play ・ rule of law ・ different ways of life, beliefs and opinions ・ the environment - with a desire to learn - diligent - committed to core and sustaining values

Appendix 3

Developing Values and Attitudes in Science Education

It is important for people to be aware that science is based upon everyday values. Indeed, science is in many respects the systematic application of some highly regarded human values and attitudes - integrity, diligence, fairness, curiosity, openness to new ideas, skepticism and imagination. Scientists do not invent any of these values, and they are not the only people who hold them. But the broad field of science does incorporate and emphasize such values and demonstrates how important they are for advancing human knowledge and welfare. Therefore, if science is taught effectively, the result will be to reinforce such desirable human attitudes and values.

Science education is in a particularly strong position to foster the following values and attitudes - curiosity, openness to new ideas, and informed scepticism.

Science thrives on curiosity - and so do children. Science education fosters curiosity and teaches children how to channel that curiosity in productive ways.

New ideas are essential for the growth of science and for human activities in general. People with closed minds miss the joy of discovery and satisfaction of intellectual growth. As the purpose of science education is not exclusively to produce scientists, it should help all students understand the great importance of carefully considering ideas, and the push and pull of conflicting ideas.

Science is characterized as much by scepticism as by openness. Before a new theory is received it has to be borne out by evidence, has to be argued with explanations, and is tested for logical consistency with other existing tested principles. Acceptance of a new theory is a process of verification and refutation. Science education can help students to develop a healthy balance in their own minds between openness and skepticism.

Taken together, these values, attitudes and skills can be thought of as habits of mind because they all relate directly to a person's outlook on knowledge and learning and ways of thinking and acting. The thinking skills associated with science are in fact essential tools for both formal and informal learning to prepare young people for life beyond school and for a lifetime of participation in a knowledge-based, scientific and technological world.

Exemplars on the development of values and attitudes in science education can be found in the website - http://www.cdc.org.hk/science.

Appendix 4

New Approaches for the General Studies Curriculum

Appendix 4

New Approaches for the General Studies Curriculum

The aims of school education, as stated in Education Commission's Reform Proposals, are "to motivate students to construct a core of basic knowledge and develop their basic abilities and attitudes to prepare them for the building of a learning and civilized society". To prepare students to face their future challenges in the 21st century, the General Studies curriculum bears the notions of developing students' understanding about themselves, the society and the world, maintaining healthy personal development, cultivating positive personal and social values and attitudes, developing their interest and curiosity in natural phenomena and the physical world, cultivating care and concern for environmental conservation, and developing their ability to inquire and solve problems with special reference to those related to the impact of science and technology on society.

The General Studies curriculum is designed in the belief that students' learning experiences are connected and not compartmentalized. The curriculum embodies core elements of learning in the Key Learning Areas of Personal, Social and Humanities Education (PSHE), Science Education (SE) and Technology Education (TE). The learning elements are integrated into various topics relating to students' daily experiences, so as to help them develop a holistic view of themselves as individuals in the community, their place in the natural world, and the interaction between human beings and the environment. Six strands of learning are identified:

- Health
- Environment
- Community
- National Identity and the Chinese Culture
- Global Understanding and the Information Era
- Science and Technology in Everyday Life

Details of the proposed core elements of these areas can be found in the consultation document of General Studies.

To enhance a smooth interface with pre-primary education, the curriculum for Primary 1-2 will emphasize personal and social education. The curriculum for Primary 3-6 will consist of core elements of learning in PSHE, SE and TE. Elements of learning from other KLAs, such as the languages, will also be integrated with those of General Studies where appropriate.

Appendix 4

Students will gain diversified learning experiences through active participation in learning activities such as project learning, service learning, scientific investigation and hands-on activities related to science and technological issues. Resources from community establishments, such as museums, community organisations, public and private bodies, will be utilized to promote life-wide learning.

Appendix 5

Proposal on A New Science and Technology Curriculum at Senior Secondary Level

Appendix 5

Background

In the *"Learning for Life, Learning through Life - Reform Proposals for the Education System in Hong Kong"* published by the Education Commission in September 2000, there is the suggestion to introduce a new subject called *Integrated Science and Technology* at the S4-5 level. The subject is among those that aim to provide students with a broad and balanced curriculum at the senior secondary level. It is particularly valuable to non-science students in providing them with additional learning experiences with regard to modern scientific and technological developments.

Appendix 5

Rationale

The new science and technology curriculum aims at enabling students to:

- have a better understanding of the scientific and technological world;
- develop better capabilities in interpreting, analyzing and evaluating scientific and technological data or information;
- acquire the skills to solve simple scientific and technological problems;
- be aware of the implications of scientific discoveries and technological developments;
- appraise the impact of scientific discoveries and technological developments; and
- develop a positive attitude towards the use and misuse of scientific discoveries and technological developments.

There will be a close integration between knowledge domains and daily life examples, as well as between scientific theories and technological applications. The integration helps students develop a holistic view about the roles of science and technology in the modern world.

The knowledge and skills acquired through the subject help students develop the capability to cope with challenges of the changing world, and prepare them for a better adult and working life. Students' awareness of the implications and impact of scientific discoveries and technological developments also helps them make rational judgements and decisions as regards the future shaping of the scientific and technological world.

Appendix 5

Curriculum Outline

The requirements of the subject will be as follows:

- a core module on the nature and development of science and technology;
- 2 optional modules selected from a list covering the different strands of science and technology education; and
- an independent study project.

Each of the optional modules takes 40 hours of study (i.e. 60 forty-minute periods). The core module and the independent study project make up another 40 hours of study, giving a total of 120 hours for the whole course.

A tentative list of the optional modules and their content is as follows:

- *Health Science* - food and health, growth and development, health and diseases, community health
- *Environmental Science* - the changing atmosphere, living things and their environment, energy and resources, quality of the environment, environment and sustainability
- *Telecommunication* - telephone, radio and TV broadcast, mobile phone, communication satellite, communication through computer networks
- *Graphical Communication* - development and application of graphical communication, basic presentation techniques, application of computer graphics, desktop publishing, simple image processing
- *Design and Control* - designing for human needs, appreciation and design considerations, applications of control systems in daily life, control systems and devices, simple control system design and construction

The independent study project can be based upon the core module or the optional modules, or any combination of them. It can take the form of a scientific investigation, a technology learning activity, or a piece of creative writing on a scientific or technological issue.

The teaching and learning of each module will be supported by a variety of learning activities including information search, self-exploratory investigation, experimental investigation, design and making, discussion and debate, role-playing, problem-solving activities, and decision-making exercises.

Appendix 5

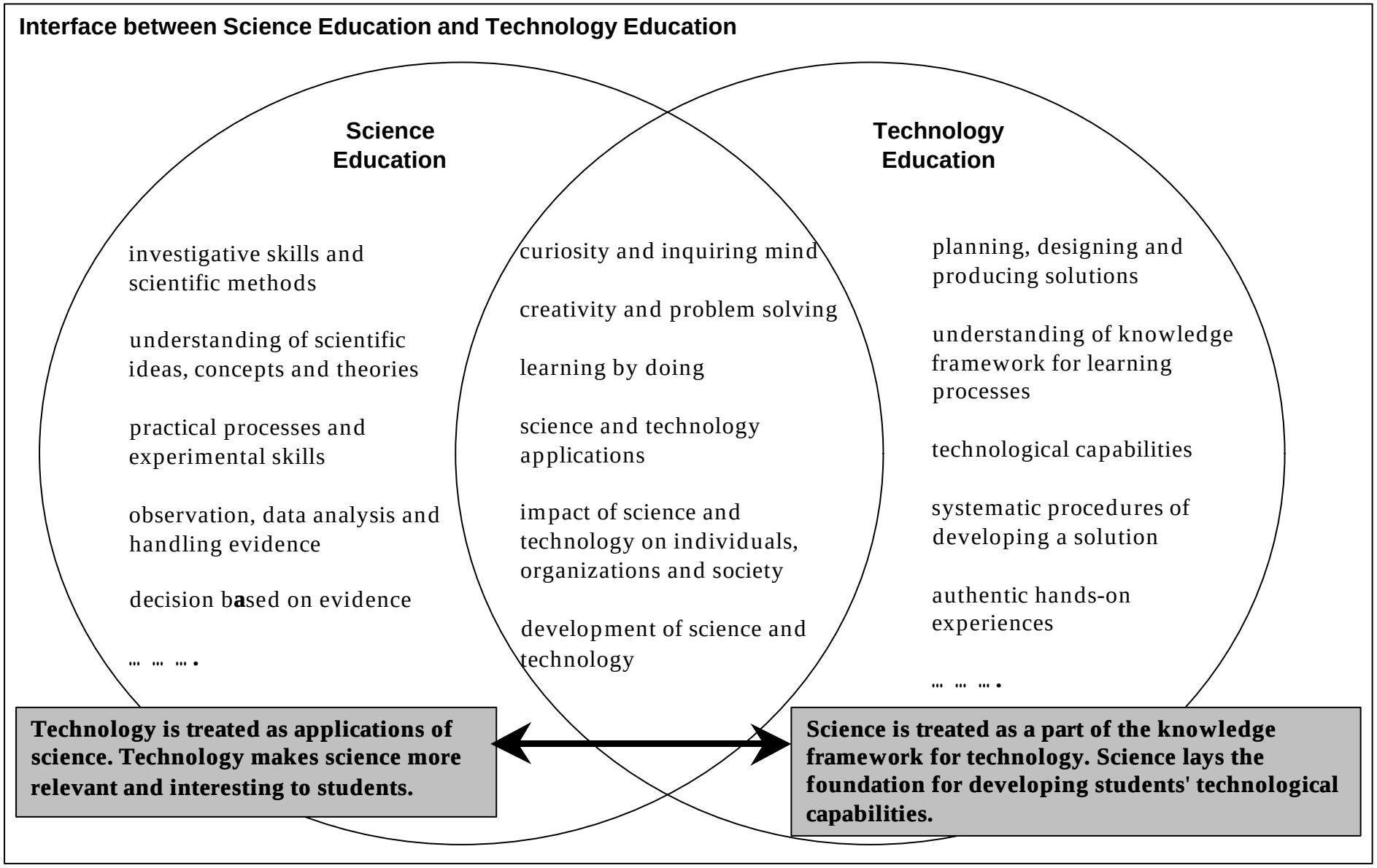
Further Development

The content of the modules will be revised and updated regularly in the light of new scientific and technological developments. A wider choice of modules will also be offered if students show interest in the subject.

The subject may be developed into a 3-year course for students in the new senior secondary curriculum. In that case, students will be required to study 2 more modules for the additional year. The modules may also be grouped into 2 or 3 categories (*science-based*, *technology-based*, and *neither*) for them to have a specialised study or a balanced curriculum depending on the student's choice.

Appendix 6

Relationship of Science and Technology Education


Interface between Science Education and Technology Education
Science Education
investigative skills and scientific methods
understanding of scientific ideas, concepts and theories
practical processes and experimental skills
observation, data analysis and handling evidence
decision based on evidence
… … ….
curiosity and inquiring mind
creativity and problem solving
learning by doing
science and technology applications
impact of science and technology on individuals, organizations and society
development of science and technology
Technology Education
planning, designing and producing solutions
understanding of knowledge framework for learning processes
technological capabilities
systematic procedures of developing a solution
authentic hands-on experiences
… … ….
Technology is treated as applications of science. Technology makes science more relevant and interesting to students.
Science is treated as a part of the knowledge framework for technology. Science lays the foundation for developing students' technological capabilities.

Promoting Technology Education through Science Education

Learning Elements in Technology Education	Exemplars in Science Education
Technology Capability	**Learners** • apply scientific principles in design and problem solving processes.
Understand Technological Activities	**Learners** • use and apply scientific values, such as fair testing, logical reasoning, systematic examination of the enhancement of the quality of technological activities.
Technology and People	**Learners** • use scientific understanding in assessing the impact of technology on the environment and on themselves such as the impact of the utilization of nuclear power on the community, the development of genetic engineering, etc.

Promoting Science Education through Technology Education

Learning Elements in Science Education	Exemplars in Technology Education
Design and carry out scientific investigations	**Learners** • conduct meaningful investigations with daily relevance and realization of products / models in the form of technological activities that provide information and direction for scientific inquiry in the natural and man-made world. • conduct technological activities such as design and realization of tools and instruments that facilitate the acquisition and examination of scientific facts & knowledge.
Acquire and apply science concepts and principles	**Learners** • understand the application of scientific concepts in various technology contexts, such as the process of changing the properties of materials to meet specific requirements.
Understand the inter-connections between science, technology and society	**Learners** • use technological understanding to assess the impact of science such as the impact of the advancement of biotechnology on society.