Integrated Science

Science Education Key Learning Area

New Senior Secondary Curriculum and Assessment Guide (Secondary 4-6)

Integrated Science

Jointly prepared by the Curriculum Development Council and
the Hong Kong Examinations and Assessment Authority

March 2007

Contents

PREAMBLE

The Education and Manpower Bureau (EMB) stated in its report[1] in 2005 that the implementation of a three-year senior secondary academic structure would commence at Secondary 4 in September 2009. The senior secondary academic structure is supported by a flexible, coherent and diversified senior secondary curriculum aimed at catering for students' varied interests, needs and abilities. This Curriculum and Assessment (C&A) Guide is one of the series of documents prepared for the senior secondary curriculum. It is based on the goals of senior secondary education and on other official documents related to the curriculum and assessment reform since 2000, including the *Basic Education Curriculum Guide* (2002) and the *Senior Secondary Curriculum Guide* (2007). To gain a full understanding of the connection between education at the senior secondary level and the basic education level, and how effective learning, teaching and assessment can be achieved, it is strongly recommended that reference should be made to all related documents.

This C&A Guide is designed to provide the rationale and aims of the subject curriculum, followed by chapters on the curriculum framework, curriculum planning, pedagogy, assessment and use of learning and teaching resources. One key concept underlying the senior secondary curriculum is that curriculum, pedagogy and assessment should be well aligned. While learning and teaching strategies form an integral part of the curriculum and are conducive to promoting learning to learn and whole-person development, assessment should also be recognised not only as a means to gauge performance but also to improve learning. To understand the interplay between these three key components, all chapters in the C&A Guide should be read in a holistic manner.

The C&A Guide is jointly prepared by the Curriculum Development Council (CDC) and the Hong Kong Examinations and Assessment Authority (HKEAA). The CDC is an advisory body that gives recommendations to the HKSAR Government on all matters relating to curriculum development for the school system from kindergarten to senior secondary level. Its membership includes heads of schools, practising teachers, parents, employers, academics from tertiary institutions, professionals from related fields/bodies, representatives from the HKEAA and the Vocational Training Council (VTC), as well as officers from the EMB. The HKEAA is an independent statutory body responsible for the conduct of public assessment, including the assessment for the Hong Kong Diploma of Secondary Education (HKDSE). Its governing council includes members drawn from the school sector, tertiary institutions and government bodies, as well as professionals and members of the business community.

[1] The report is *The New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong*.

The C&A Guide is recommended by the EMB for use in secondary schools. The subject curriculum forms the basis of the assessment designed and administered by the HKEAA. In this connection, the HKEAA will issue a handbook to provide information on the rules and regulations of the HKDSE examination as well as the structure and format of public assessment for each subject.

The CDC and HKEAA will keep the subject curriculum under constant review and evaluation in the light of classroom experiences, students' performance in the public assessment, and the changing needs of students and society. All comments and suggestions on this C&A Guide may be sent to:

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Acronyms

ApL	Applied Learning
C&A	Curriculum and Assessment
CDC	Curriculum Development Council
EMB	Education and Manpower Bureau
HKALE	Hong Kong Advanced Level Examination
HKDSE	Hong Kong Diploma of Secondary Education
HKEAA	Hong Kong Examinations and Assessment Authority
HKSAR	Hong Kong Special Administrative Region
IT	Information Technology
KLA	Key Learning Area
OLE	Other Learning Experience
R&D	Research and Development
P1/2/3/4/5/6	Primary 1/2/3/4/5/6
S1/2/3/4/5/6/7	Secondary 1/2/3/4/5/6/7
SBA	School-based Assessment
SEN	Special Educational Needs
STSE	Science, Technology, Society and Environment
VTC	Vocational Training Council

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Chapter 1 Introduction

This chapter provides the background, rationale and aims of Integrated Science as an elective subject in the three-year senior secondary curriculum, and highlights how it articulates with the junior secondary curriculum, post-secondary education, and future career pathways.

1.1 Background

The Education Commission's education blueprint for the 21st Century, ***Learning for Life, Learning through Life – Reform proposals for the Education System in Hong Kong*** **(2000)**, highlighted the vital need for a broad knowledge base to enable our students to function effectively in a global and technological society such as Hong Kong's, and all subsequent consultation reports have echoed this. ***The New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong*** **(2005)** advocated the development of a broad and balanced curriculum emphasising whole-person development and preparation for lifelong learning. Besides the four core subjects – Chinese Language, English Language, Mathematics and Liberal Studies – students are encouraged to select two or three elective subjects from different Key Learning Areas (KLAs) according to their interests and abilities, and also to engage in a variety of essential learning experiences such as aesthetic activities, physical activities, career-related experiences, community service, and moral and civic education. This replaces the traditional practice of streaming students into science, arts and technical/commercial subjects.

Study of the three different areas of biology, chemistry and physics often complement and supplement each other. In order to provide a balanced learning experience for students studying sciences, the following elective subjects are offered under the Science Education KLA:

- **Biology, Chemistry and Physics**
  These subjects are designed to provide a concrete foundation in the respective disciplines for further studies or careers.

- **Science**
  This subject operates in two modes. Mode I, entitled Integrated Science, adopts an interdisciplinary approach to the study of science, while Mode II, entitled Combined Science, adopts a combined approach. The two modes are developed in such a way as to provide space for students to take up elective subjects from other KLAs after taking one or more elective(s) from the Science Education KLA.

Mode I: Integrated Science

This is designed for students wishing to take up one elective subject in the Science Education KLA. It serves to develop in students the scientific literacy essential for participating in a dynamically changing society, and to support other aspects of learning across the school curriculum. Students taking this subject will be provided with a comprehensive and balanced learning experience in the different disciplines of science, while leaving space for them to widen their horizons by taking subjects from other KLAs.

Mode II: Combined Science →
- Combined Science (Physics, Chemistry)
- Combined Science (Biology, Physics)
- Combined Science (Chemistry, Biology)

Students wishing to take two elective subjects in the Science Education KLA are recommended to take one of the Combined Science electives together with one specialised science subject. Each Combined Science elective contains two parts, and these should be the parts that complement the discipline in which they specialise. Students are, therefore, offered three possible combinations:

- Combined Science (Physics, Chemistry) + Biology
- Combined Science (Biology, Physics) + Chemistry
- Combined Science (Chemistry, Biology) + Physics

1.2 Implementation of Science Subjects in Schools

The five separate Curriculum and Assessment Guides for the subjects of Biology, Chemistry, Physics, Integrated Science and Combined Science are prepared for the reference of school managers and teachers, who are involved in school-based curriculum planning, designing learning and teaching activities, assessing students, allocating resources and providing administrative support to deliver the curricula in schools. Arrangements for time-tabling and deployment of teachers are given in **Appendix 1**.

This ***Integrated Science Curriculum and Assessment Guide*** is concerned with the delivery of Mode I of the Senior Secondary Science Curriculum.

1.3 Rationale

The Integrated Science curriculum aims to develop in students a broad and sound knowledge base to meet the challenges of living in a technologically advanced society. The curriculum adopts an interdisciplinary thematic approach. Students taking this subject will benefit from learning science concepts from different disciplines of science in contexts which are expected to have enduring relevance to them in the next decade and beyond. Through systematic inquiry, they will develop scientific knowledge and skills to help them evaluate the impact of scientific and technological developments.

The Integrated Science curriculum follows the general direction for the development of the school science curriculum set out in the ***Science Education Key Learning Area Curriculum Guide (Primary 1 – Secondary 3)*** **(2002)**, which put forward a framework for arranging major learning elements in science into six strands: 'Scientific Investigation', 'Life and Living', 'The Material World', 'Energy and Change', 'The Earth and Beyond' and 'Science, Technology, Society and Environment (STSE)'. These six strands are inter-related and can be represented diagrammatically as follows:

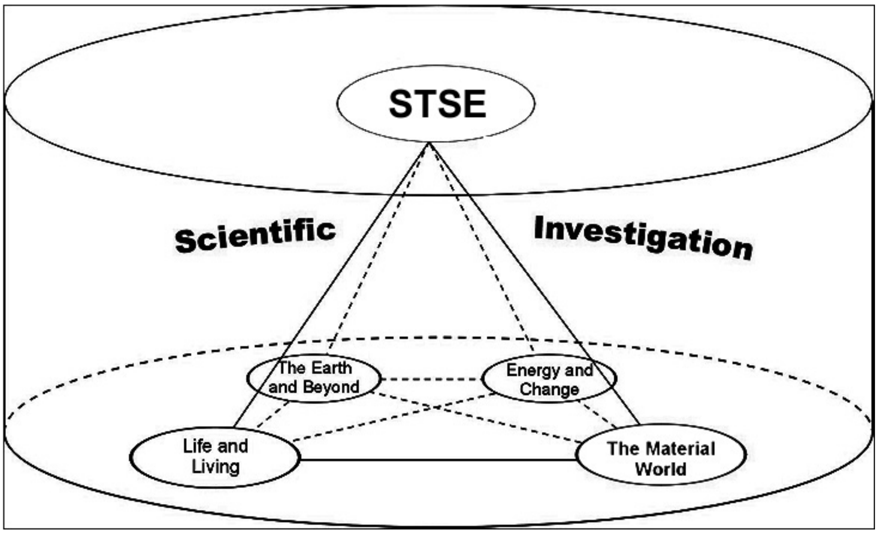

Figure 1.1 Inter-relationship between the six strands in the school science curriculum

The Integrated Science curriculum aims to empower students to be inquisitive, reflective and critical thinkers, by equipping them with a variety of ways of looking at the world and by emphasising the importance of evidence in forming conclusions. It is believed that in a technologically advanced society, like Hong Kong's, many people will find a knowledge and understanding of science concepts useful to their work, and a competency in scientific inquiry of great value in creative problem solving in life.

1.4 Curriculum Aims

The overarching aim of the Integrated Science curriculum is to provide learning experiences that will enable students to develop scientific literacy, so that they can participate actively in our rapidly changing knowledge-based society, prepare for further study or a career in fields where a knowledge of science will be useful; and become life-long learners in science and technology.

The broad aims of the curriculum are to enable students to:

- develop interest in, and maintain a sense of wonder and curiosity about, the natural and technological world;
- acquire a broad and general understanding of key science ideas and explanatory frameworks of science, and appreciate how the ideas were developed and why they are valued;
- appreciate and develop an understanding of the nature of scientific knowledge;
- develop skills for making scientific inquiries;
- develop the ability to think scientifically, critically and creatively, and to solve problems individually or collaboratively in science-related contexts;
- use the language of science and communicate ideas and views on science-related issues;
- make informed decisions and judgments about science-related issues;
- be aware of the social, ethical, economic, environmental and technological implications of science and develop an attitude of responsible citizenship; and
- develop conceptual tools for thinking and making sense of the world.

1.5 Interface with Junior Secondary Curriculum and Post-secondary Pathways

To ensure a smooth transition between junior and senior secondary, schools should plan for the interface with the junior secondary science curriculum. Teachers should refer to the learning targets and objectives of Key Stage 3 in the ***Science Education Key Learning Area Curriculum Guide (Primary 1 – Secondary 3)*** **(2002)**, as well as the ***CDC Science (S1-3) Syllabus*** **(1998)**. Schools should make arrangements to complete the core parts of the Science (S1-3) syllabus before starting this curriculum.

While building on the foundations developed in the Science (S1-3) curriculum, Integrated Science provides students with a wider range of scientific ideas and considers them in greater depth. Students are given many opportunities to reflect on issues and controversies in matters involving science and technology, and so become better informed and more sophisticated consumers of science-related information. The kinds of reasoning used to develop arguments, such as assessing the certainty of data, evaluating evidence about correlation and cause, and assessing the risks and benefits in using certain technologies, all contribute to preparing students to deal sensibly with everyday problems. By broadening and enriching their knowledge, skills and experiences in science, the Integrated Science curriculum also provides a firm foundation for further study, vocational training or work. It opens up a variety of possible post-secondary educational and careers pathways including Business Administration, Law, Dental Surgery, Risk Management Science, Actuarial Science, Information Engineering, Sports Sciences, etc.

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Chapter 2 Curriculum Framework

The curriculum framework for Integrated Science embodies the key knowledge, skills, values and attitudes that students are to develop at senior secondary level. It forms the basis on which schools and teachers plan their school-based curriculum and design appropriate learning, teaching and assessment activities.

2.1 Design Principles

The design of this curriculum is founded on the following principles, which are in line with those recommended in Chapter 3 of ***The New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong*** **(2005)**:

- Prior knowledge
  This curriculum is built on the foundation developed in Basic Education. It follows the general direction for the development of the Science Education curriculum set out in the ***Science Education Key Learning Area Curriculum Guide (Primary 1 – Secondary 3)*** **(2002)**, and extends the prior knowledge, skills and positive values and attitudes that students develop through the Science (S1-3) curriculum.

- Balance between breadth and depth
  This curriculum is designed for students taking one elective subject in the Science Education KLA. Students taking this subject will be provided with comprehensive and balanced learning experiences in the different disciplines of science. A thematic approach which focuses on the **key ideas in science** has been adopted**.** The curriculum does not cover all the areas in the traditional high school Biology, Chemistry and Physics curricula but, for selected topics, the treatment is deeper and the **key ideas in science**, **unifying concepts** and **nature of science** are fully illustrated.

- Balance between theoretical and applied learning
  A thematic approach has been adopted and students will benefit from learning concepts and scientific ideas in contexts that bring out their relevance to everyday life. The emphasis of the curriculum is on an understanding of science to prepare our students to participate in discussion, debate and decision-making about the application and implications of science and technology.

- Balance between essential learning and a flexible and diversified curriculum
  This curriculum consists of a compulsory part, made up of eight modules and an elective part. Students are allowed to choose two from the three elective modules at S6, according to their interests and aspirations for the future. The elective modules are designed to extend the knowledge and skills acquired through compulsory modules and provide opportunities for students to apply scientific concepts and understandings in an integrated manner.

- Learning how to learn
  The overarching aim of the curriculum is to nurture students' scientific literacy so that they develop 'thinking tools' for reflecting on science, see the coherence among seemingly diverse sets of ideas, and discover **unifying concepts** (such as systems, order and organisation) that pervade science and transcend disciplinary boundaries. These are powerful conceptual tools that enable students to see the overarching coherence in our natural world. The curriculum also draws attention to the understanding of the **nature of science**, that is, the process by which scientific knowledge is constructed and validated. For students, both the ability to see beyond facts and the development of a scientific way of thinking and knowing through inquiry are essential for both formal and informal learning and for participating intelligently in society as a whole.

- Coherence
  The scientific explanations students acquire and the logical thinking they develop in this curriculum will support their studies in other areas of secondary education. There are many opportunities for cross-curricular learning across core and other elective subjects.

- Multiple progression pathways
  One consequence of the advancing globalization and technological dependence of our society is that even people outside the science professions are finding that issues of concern to them tend to have a scientific dimension. By studying this subject, our students will be better equipped to deal sensibly with everyday problems involving the use of evidence, quantitative considerations, logical arguments and uncertainty. The knowledge, thinking and problem-solving skills acquired in the curriculum will help students to pursue further study in a wide range of academic and vocational/professional programmes in tertiary institutions, e.g. Business Administration, Law, Dental Surgery, Risk Management Science, Actuarial Science, Information Engineering and Sports Science.

2.2 Learning Targets

In adopting a thematic approach based on contexts of daily relevance, it is expected that students will develop understanding of (i) the key ideas in science, (ii) the nature of science and (iii) unifying concepts in science. The following diagram summarises the relationship between the various elements of the Integrated Science curriculum.

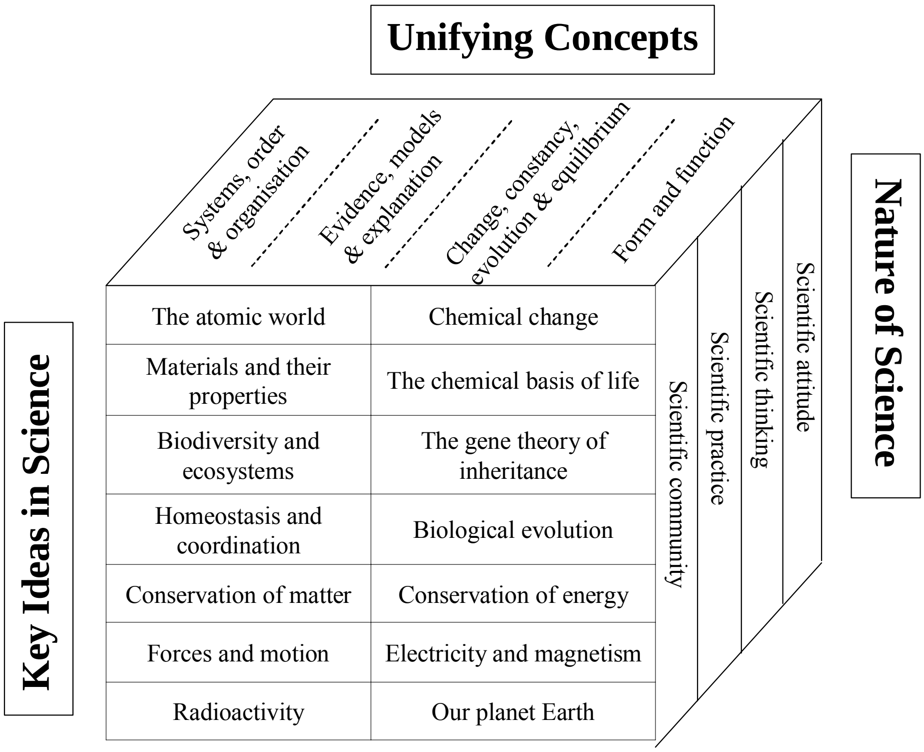


Figure 2.1 Framework of the Integrated Science curriculum

2.2.1 Key Ideas in Science

The modules in this curriculum are structured around a number of key ideas in science. Students will be led to probe situations of interest and daily relevance, such as: "What is the chemical basis of life?"; "Is the Earth warming up?"; "How do energy and matter interact?"; "Why do we sometimes fall sick?"; and "Is radiation a friend or a foe?". Explanatory stories will be used to provide students access to "How do we know?". It is intended that students should focus on a small number of key ideas so that they can work on them in depth to gain a better understanding and be able to apply what they have learned. As seen in the diagrammatic framework (Figure 2.1), the following key ideas in science have been selected after consulting a range of international curriculum documents and considering their relevance and usefulness to our students:

- The atomic world;
- Chemical change;
- Materials and their properties;
- The chemical basis of life;
- Biodiversity and ecosystems;
- The gene theory of inheritance;
- Homeostasis and coordination;
- Biological evolution;
- Conservation of matter;
- Conservation of energy;
- Forces and motion;
- Electricity and magnetism;
- Radioactivity;
- Our planet Earth

2.2.2 Nature of Science

The Integrated Science curriculum is concerned with the process by which scientific knowledge is constructed and validated. In the course of study, students will be led to stand back and examine what has happened, to go through some of the intellectual explorations, to analyse, and to assess the line of thought, recognising the elements of its logic, its strength, and its limitations . In this way students will develop an understanding of how reliable knowledge about the natural world is obtained. The different facets of the nature of science that will be highlighted in the curriculum are outlined below:

- Scientific attitude: searching for truth; science is based on evidence and empirical standards; and it also encourages innovation and scepticism
- Scientific thinking: scientific knowledge is built on creative thinking; the application of deductive and inductive logic leads to the emergence of new scientific theories, which are then tested empirically; scientific knowledge, while durable, has a tentative character
- Scientific practice: precise experimental design and proper instrumentation; prudent handling of quantitative and qualitative data; honest reporting
- Scientific community: community with a collective wisdom, encouraging free exchange and open-minded discussion and debate; scientists critically assess new discoveries via a peer-reviewing system

2.2.3 Unifying Concepts

The Integrated Science curriculum encompasses concepts and understandings in the six strands of the Science Education KLA (Figure 1.1). Apart from widening students' exposure to contemporary science relevant to their daily lives, the curriculum also attempts to provide some conceptual tools with which students can proceed beyond the facts. Thus, the unifying concepts that pervade science and transcend disciplinary boundaries are highlighted. These unifying concepts are powerful conceptual tools, which help students see the overarching coherence in our understanding of the natural world. The unifying concepts covered in this curriculum are:

- Systems, order, and organisation: These are ways of observing and describing phenomena that are related to each other and/or work together as a whole.
  (a) Systems: an organised group of related objects or components that form a whole. Thinking and analysing in terms of systems will help students to keep track of mass, energy, objects, organisms and events. Drawing the boundary of a system well can make the difference between understanding and not understanding what is going on. For instance, the conservation of mass during burning was not recognised for a long time, because the gases produced were not included in the system whose weight was measured.
  (b) Order: an arrangement showing patterns or sequence. Examples include the seasonal weather patterns and the order of behaviour of chromosomes during cell replication.
  (c) Organisation: the act or process of being organised, a condition of things being put into a structural framework according to a particular hierarchy. Examples include the periodic table of the elements, and the different levels of organisation in living things such as cells, tissues, organs and systems.

- Evidence, models and explanation: Scientists use evidence and models to understand, explain and/or predict scientific phenomena.
  (a) Evidence: consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Examples of evidence include the smell of food (evidence that dinner is ready), and water droplets formed on a glass (evidence of the content inside the glass being cooler).
  (b) Models: representations that are taken to illustrate real systems, objects, concepts, events, or classes of events. They can be used to explain, predict and study how real objects work. Models can be physical, conceptual, or

mathematical. Examples of physical models include the molecular structure of chemical substances and the cell model; and examples of conceptual models include models of the atom showing the nucleus and orbiting electrons, and gas molecules colliding to produce pressure. An example of a mathematical model is the equation representing the exponential growth in the number of bacteria undergoing binary fission (Number of bacteria = 2^n, where n = number of division).

- Change, constancy, evolution and equilibrium: Change, constancy, evolution and equilibrium all describe states of being of a scientific phenomenon.
  (a) Change: a process resulting in alteration. Examples include the chemical changes in combustion or the transformation of electrical energy to heat and light energy in a complete circuit with a cell and a bulb.
  (b) Constancy: the state of being unchanged or some aspects of systems that have the remarkable property of always being conserved. Examples include the speed of light and the conservation of energy.
  (c) Evolution: a series of changes, some gradual and some sporadic, that account for the present form and function of objects, organisms and natural systems. The general idea of evolution is that the present is a consequence of materials and forms of the past. Examples include ecological succession, and climatic changes due to enhanced greenhouse effect.
  (d) Equilibrium: a physical state in which forces or changes occur in opposite and offsetting directions. The ultimate fate of most physical systems, as energy available for action dissipates, is that they settle into a state of equilibrium. Examples include a falling rock coming to rest at the foot of a cliff, and maintenance of human body temperature.

- Form and function:
  (a) Form: the shape and structure of an object
  (b) Function: the role that an object, activity or job has, or the purpose for which it is used.

  Form and function are usually interrelated. For example, a fish has fins (form), which allow it to swim (function); and to improve the efficiency (function) of a boat, it is designed with a streamlined body (form) so as to reduce friction. In the modern technological world, artefacts are always designed (form) with their function in mind.

2.3 Curriculum Structure and Organisation

2.3.1 Curriculum Structure

The curriculum consists of a compulsory part, made up of eight modules, and an elective part, made up of three modules. Students are required to complete the compulsory part and choose two out of the three modules offered in the elective part. All the modules focus on a theme. Organising the concepts and scientific ideas in themes helps to bring out their relevance to everyday life and so makes the learning more meaningful to students.

Elective modules are included in the curriculum to offer choice to students with different interests and aspirations, and to prepare them for different tertiary programmes and career paths. The elective modules extend the knowledge and skills acquired through the compulsory modules and provide opportunities for students to apply their scientific concepts and understanding in an integrated manner. They also illustrate ways in which science is applied in contemporary life and involve students in extended problem-solving investigations. The following diagram illustrates the interconnection between the modules in the compulsory part and those in the elective part:

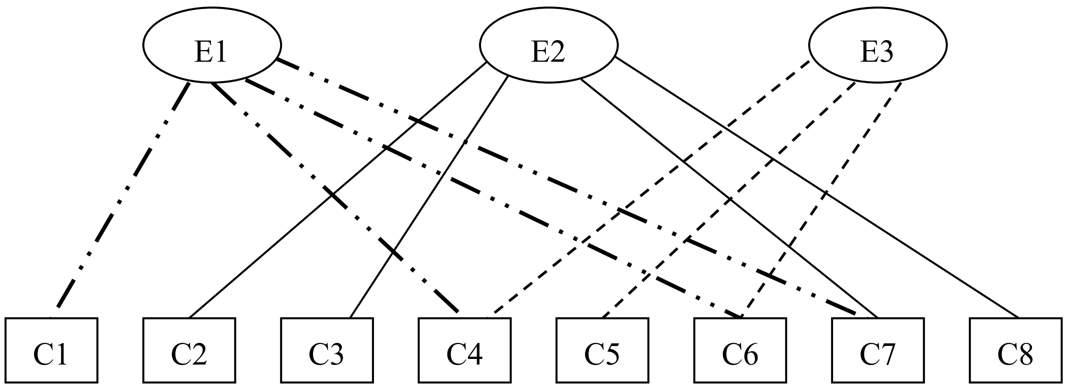


Figure 2.2 Interconnection between the compulsory and elective modules

A total of 270 hours is allocated to cover the whole curriculum. Of the 270 hours, 14 are used for scientific investigation, to develop students' skills for scientific inquiry and a scientific attitude. Teachers can decide on the lesson hours for scientific investigation in different modules, and can use the 14 hours as time for students to carry out cross-theme/discipline investigations of a relatively large scale. An estimate of the number of hours required for the compulsory and elective parts is shown below:

	Suggested lesson time (Hours)
Scientific Investigation Fourteen hours of the total curriculum time are allocated for relatively large-scale or cross-theme/discipline investigations. However, simple investigations requiring shorter periods of time should be subsumed in other practical work in the lesson time suggested for each section.	14
<u>Compulsory Modules</u>	
C1 Water for Living	24
C2 Balance within Our Body	24
C3 Science in a Sprint	24
C4 Chemical Patterns	24
C5 Electrical Enlightenment	24
C6 Balance in Nature	24
C7 Radiation and Us	24
C8 From Genes to Life	24
<u>Elective Modules (2 out of 3)</u>	
E1 Energy, Weather and Air Quality	32
E2 Keeping Ourselves Healthy	32
E3 Chemistry for World Needs	32

Figure 2.3 Suggested time allocation

2.3.2 Curriculum Organisation

In this document, the content of each module is organised into two major parts: *Overview* and *Table of Content.*

The introduction in the *Overview* explains briefly the philosophy of the module and the context. It outlines the major theme and, where appropriate, the nature of science and the unifying concepts the module is designed to introduce. Focusing questions are included to help students direct their learning. A diagrammatic representation of the module organisation is also provided as a blueprint of the major concepts and interconnections. Possible sequences for the delivery of some modules are also included for teachers' reference. However, teachers are encouraged to draw up schemes of work to suit the needs, interests and abilities of their students.

The *Table of Content* is organised into three parts to elaborate on the theme:

- The **'Students should learn'** column lists the knowledge content
- The **'Suggested learning and teaching activities'** column suggests learning activities to facilitate students' learning of the knowledge content and develop their skills. The suggested activities are not exhaustive and should not be regarded as mandatory. Teachers should exercise their professional judgment in selecting and including appropriate activities to enrich students' learning experiences.
- The **'Module highlights'** list the opportunities offered in each module for the development of the unifying concepts and nature of science. They also spell out specific values and attitudes that can be developed through the learning of the module. In addition, this list relates the science concepts developed in the module to technology, society and the environment.

Compulsory Part

(C1-C8)

2.3.3 Compulsory Part

C 1 Water for Living

Overview

Introduction

Water is an apparently simple molecule that can be found almost everywhere on Earth. It is vital to living organisms both in regulating their life processes and the environment which they inhabit. Water is believed to be a pre-requisite for the emergence of living organisms. Today, many problems in our world are related to water supply and quality, including drought, flooding and pollution.

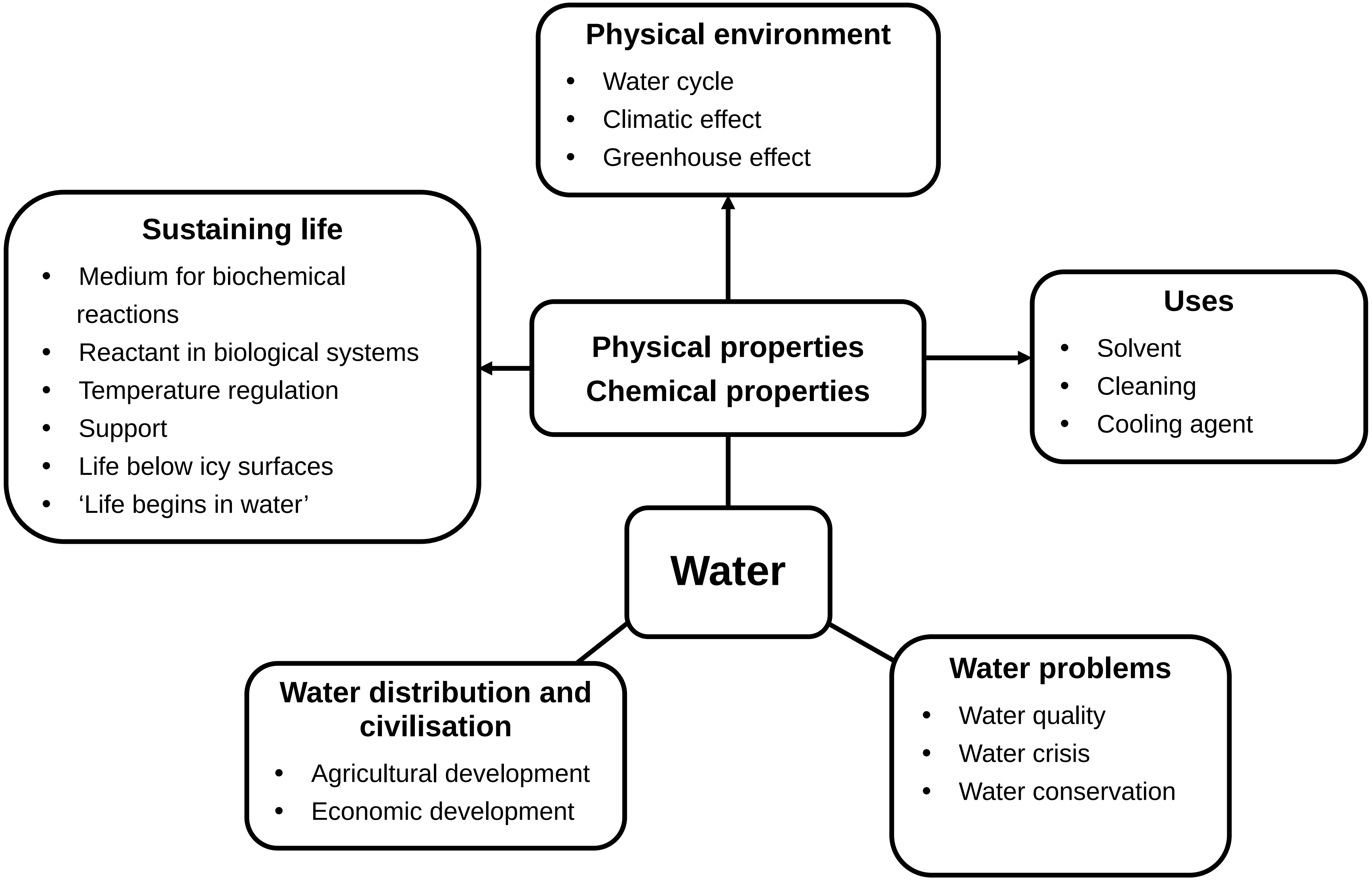
In this module, students look into the science of water as a basis of life. The unique physical and chemical properties of water render it a useful solvent, a reactant in metabolic reactions, and a temperature regulator in living organisms and our physical environment at large. Having recognised the importance of water to life, students are led to examine the impact of human activities on this shared resource and how the accessibility of clean water and a steady water supply may affect a country's development.

A number of unifying concepts are elucidated in this module. An examination of the structural adaptations needed for coping with life on land illustrates the interrelationship between form and function. Another unifying concept, constancy and change, is illustrated in the water cycle. Through examining arguments supporting or refuting the claim 'life begins in water', students will come to appreciate how evidence and their interpretations play their parts in helping scientists to make sense of the world.

Focusing Questions

- What makes water so unique as a solvent, coolant and medium for biochemical reactions to take place?
- How important is water to the proper functioning of a living organism?
- How significant is water to our physical environment?
- How does an adequate water supply influence a country's course of development?
- 'Life begins in water' – what evidence is there to support or refute this claim?

Module Organisation



Suggested Teaching Sequences

Sequence A

Set: Water problems in China (drought, desertification, soil erosion, flooding)

↓

Water distribution, use and waste

↓

Effects of human activities on the balance of water distribution and water quality

↓

Importance of water to living organisms and the physical environment

↓

The unique properties of water

↓

Water and biological evolution

Sequence B

Set: Presence of water as evidence of life

↓

Importance of water to living organisms and the physical environment

↓

The unique properties of water

↓

Water and biological evolution

↓

Water distribution, use and waste

↓

Effects of human activities on the balance of water distribution and water quality

C 1: Water for Living

Students should learn	Suggested learning and teaching activities
1.1 The unique properties of water • The size and shape of a water molecule • The intermolecular forces between water molecules (van der Waals' forces and H-bonding) • Properties of water – Solvent action of water – The dissociation of water ($H_2O \rightleftharpoons H^+ + OH^-$) and the pH scale – Maximum density at 4 ^oC – High specific heat capacity – High specific latent heat of vaporisation and fusion – The occurrence of water in all three physical states on Earth – High surface tension	• Visualise the shape of a water molecule, and the arrangement of molecules in ice and liquid water using computer software • Make cold packs – dissolving ammonium nitrate in water • Make hot packs – crystallising salt from a supersaturated solution • Simulate the formation of acid rain – bubbling SO_2 or CO_2 into water and testing the pH • Investigate the energy needed to raise the temperature of different materials by 1 ^oC
1.2 Importance of water to living organisms and biological evolution • Movement of water in and out of cells by osmosis • Roles of water in – Biochemical reactions – Transporting materials – Facilitating gas exchange – Temperature regulation – Providing support – Sustaining life below icy surfaces • Evidence that supports or refutes the claim 'Life begins in water' • Coping with life on land: structural adaptations for acquiring and conserving water, support, gas exchange and internal fertilisation	• Use models and analogies to describe how water molecules pass through cell membranes during osmosis • Preserving food using different dehydrating methods: drying, osmotic dehydration (e.g. salting), freeze drying • Internet search to appreciate the contribution of plastination to preserving biological specimens • Discuss the use of fossil records and other arguments to support or refute the claim 'Life begins in water' • Discuss why mosses are restricted to moist areas • Identify the structural adaptations found in a mudskipper for allowing it to live out of water
1.3 Importance of water to the physical environment	

• Water cycle • Influence on climate • Greenhouse effect	• Experiments to simulate cloud formation and precipitation • Internet search on the winter and summer average temperatures inland and near the coast
1.4 Effects of human activities on the balance of water distribution and water quality • Domestic and industrial uses of water • The impact on water systems of the release of substances in domestic sewage • The causes and effects of water problems (drought, desertification, soil erosion, flooding) in China • Global water distribution • The global water crisis: water management and conservation	• Experiments to simulate how water can be used as a cooling agent in a car engine • Collect newspaper clippings on how water problems may hinder the development of a country • Information search on the causes and impacts of algal blooms in Hong Kong waters • Visit a local sewage treatment plant • Develop action plans to reduce water pollution

Module highlights

In this module, students have opportunities to:

- recognise that scientists use the molecular structure of water (a physical model) to explain its physical and chemical properties
- apreciate that the physical properties (e.g. density) of water are constant and that we can use these physical properties for the identification of water
- recognise that the different roles played by water in living organisms are related to the structure and shape of water molecules (form and function)
- realise the interrelationship between adaptations and the vital functions in terrestrial organisms (form and function)
- realise the importance of evidence in assessing the validity of scientific claims (e.g. the claim that ‘Life begins in water’) and theories
- appreciate the conservation of matter in the water cycle while water changes from one physical state to another
- appreciate that some water problems (e.g. desertification) demonstrate evolution driven by gradual changes resulting from human activities over a period of time
- develop an awareness of the importance of a clean water supply to personal health and a country’s development
- develop a concern for water problems associated with developments in Hong Kong and mainland China
- develop a commitment, and make a continual effort, to reduce water pollution

C 2 Balance within Our Body

Overview

Introduction

The conditions in which life processes can take place are quite stringent, and fluctuations in the internal environment can profoundly affect the normal functioning of our cells. This module is concerned with how our body can maintain a stable internal environment.

In this module, the principles underlying the body's adjustment mechanisms are outlined. These involve negative feedback between a receptor and an effector to bring the conditions back to normal. The control of blood glucose level and the regulation of body temperature are used as illustrations.

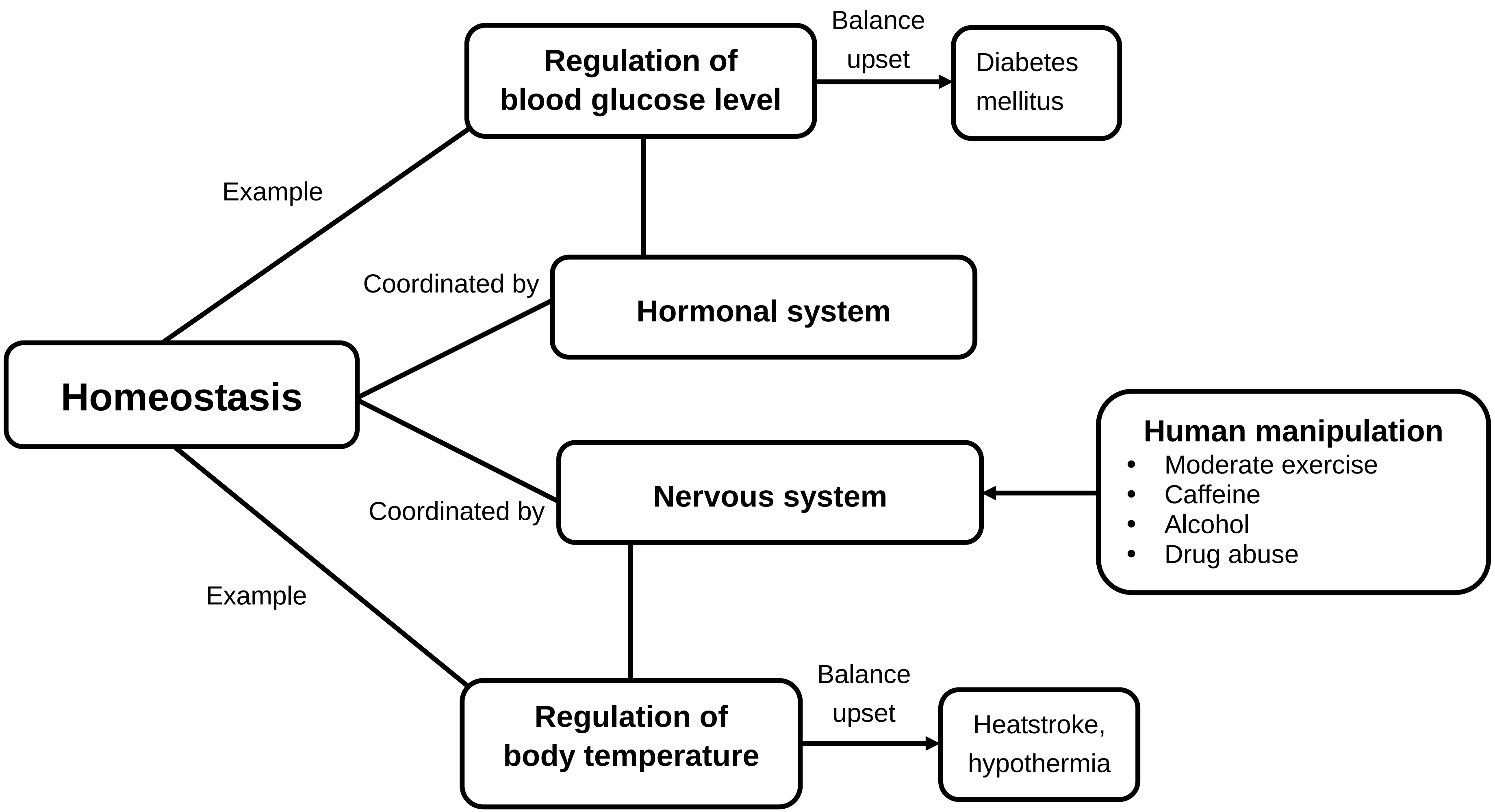
Many of the body's organs and physiological processes contribute to the above adjustment mechanism. The orderly and efficient functioning of these organs and processes require a means of coordination – that is the monitoring of activities of different parts and the flow of information among the parts through receiving, integrating and subsequently issuing appropriate commands. There are two kinds of integration in humans: nervous and hormonal. The two systems interact in a dynamic way in order to maintain the constancy of our internal environment, while permitting changes in response to a varying external environment.

Besides the self-regulation of our internal environment, we may also try to manipulate it. For example, when very busy at work, people may like to be energised by drinking a cup of coffee or feel relaxed by taking alcohol. One may also enhance one's mood with moderate exercise. The scientific basis involved is explored. However, with continuous overloading or other effects, our body may show various symptoms of stress or depression. The possible cause of depression due to low levels of specific neurotransmitters and the role of possible therapeutic drugs is also discussed.

Focusing Questions

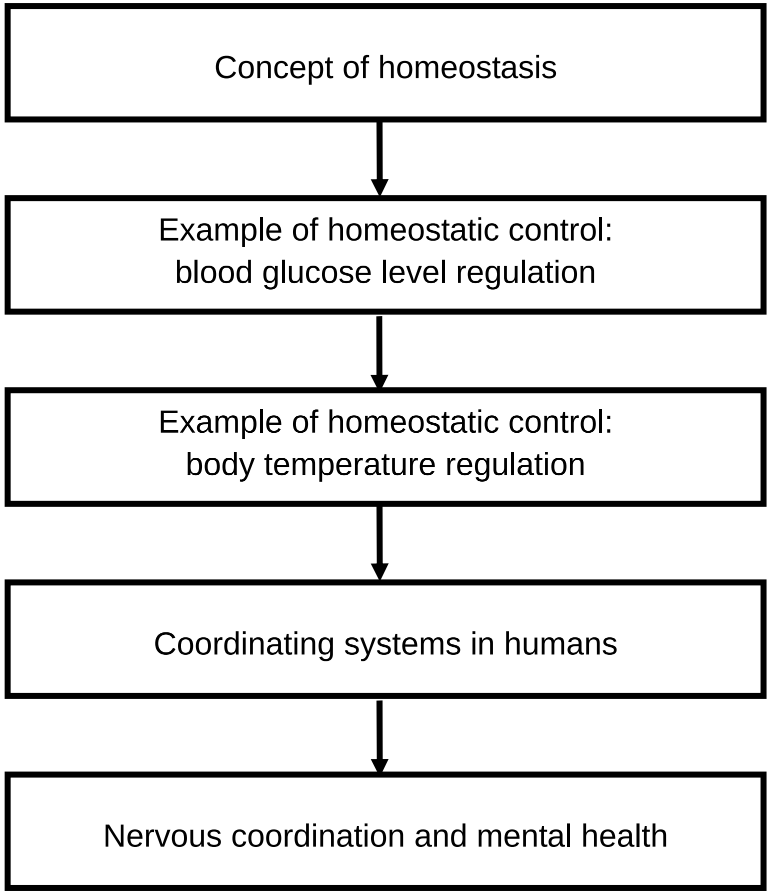
- What is homeostasis and why it is important to us?
- How is our body temperature kept constant? How does our body regulate our blood glucose level?
- How do our nervous and hormonal systems contribute towards homeostasis?
- What is the relationship between mental health and nervous coordination?

Module Organisation

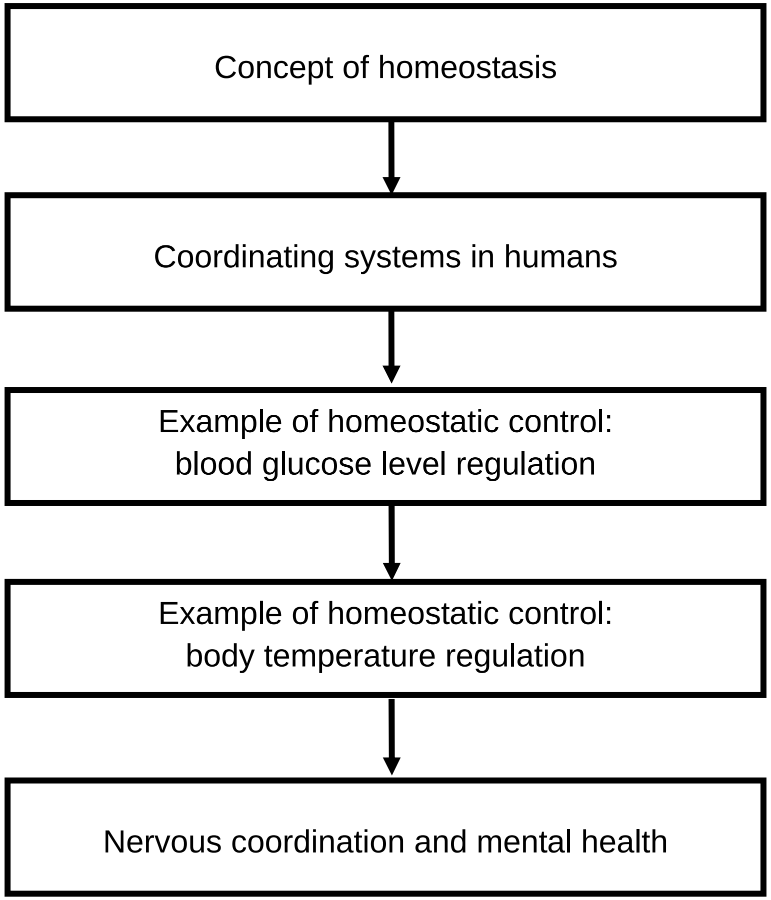


Suggested Teaching Sequences

Sequence A



Sequence B



C 2: Balance within Our Body

Students should learn	Suggested learning and teaching activities
2.1 Homeostasis • Concept of homeostasis and its significance • Control system: receptors, coordinators, effectors • Mechanism of negative feedback	• Animations to illustrate control by negative feedback in daily life (e.g. the operation of air-conditioner, the use of accelerator and brake in driving)
2.2 Regulation of body temperature • Importance of body temperature regulation – The role of enzymes in metabolism – The effect of temperature on enzyme activity • Core temperature and tolerance range, hypothermia, and heatstroke • Balancing heat loss against heat gain • Roles of different body parts in the regulation of body temperature – Receptors: skin receptors and hypothalamus – Coordinator: nervous system and hypothalamus – Effectors: sweat glands, blood vessels and erector muscles	• Design and perform investigations to study the effects of temperature on the activities of enzymes • Use audio-visual materials to show the enzyme catalysis mechanism and the effect of temperature on enzyme function • Examine a model of mammalian skin for its features in relation to temperature regulation • Activity for mapping effectors and their actions for temperature regulation • Construct concept maps to show the mechanism of temperature regulation
2.3 Regulation of blood glucose level • Importance of blood glucose level regulation • The action of pancreatic hormones on blood glucose regulation • Diabetes mellitus: types, symptoms and risk factors	• Construct concept maps to show the mechanism of blood glucose regulation • Ask students to design a pamphlet to inform teenagers about the types, symptoms, risk factors, diagnostic tests, and management of diabetes. • Test for glucose in urine
2.4 Coordinating systems in humans • Hormonal coordination – Nature of hormonal coordination • Nervous coordination – Nature of nervous coordination – Functions of the central nervous	• Examine prepared slides or electron micrographs of a neurone to study its typical structures • Examine an electron micrograph of a synapse to study its structure

system and peripheral nervous system – Role of the autonomic nervous system in homeostasis (e.g. regulation of body temperature) • The similarities and differences between hormonal and nervous coordination	• Use a model to illustrate the gross structure of the human brain • Use a model or diagram to illustrate the median vertical section of the human brain
2.5 Nervous coordination and mental health • Transmission of nerve impulse along a nerve fibre and across a synapse • Role of neurotransmitters in synaptic transmission • Mental illness in terms of imbalance of neurotransmitters or impairment of neurotransmitter reception • Role of psychiatric drugs: adjusting neurotransmitter levels or acting on neuro-receptors • Possible ways and effects of manipulating the nervous coordination pathway (e.g. taking caffeine, drinking alcohol, exercise-induced endorphin)	• Use audio-visual materials to show the conduction of nerve impulse, and the chemical transmission at the synapse • Information search on the scientific basis of the harmful effects of any one of the following: stimulants, depressants, hallucinogens, tranquillisers, narcotics, analgesics and others • Information search on the scientific basis of mental illness (e.g. psychosis and depression) and the respective therapeutic drugs

Module highlights

In this module, students have opportunities to:

- appreciate that our body is an organised system in which the well-being is maintained by the interactions among a number of sub-systems (e.g. hormonal and nervous systems)
- recognise that the components of our nervous system interact to keep our body temperature at a desirable level
- realise that the set points in a proper functioning system (e.g. body temperature kept at 37^{o}C) is maintained by dynamic equilibrium – offsetting the equilibrium results in adverse health conditions
- understand, as illustrated by the regulation of blood glucose level and body temperature, that changes are necessary for correcting any deviations from the set points
- appreciate that the conceptual model of 'lock and key' helps to depict the importance of the complementary nature of hormones and neurotransmitters and their respective receptors on the cell surface for homeostatic control
- recognise the relationship between form and function as illustrated by nerve cells
- appreciate how evidence from brain research helps to change our understanding of mental illnesses
- develop concern and take responsibility for their own health (e.g. avoiding diets that prone to the development of diabetes, taking precautions to avoid heatstroke)
- recognise ways to enhance mental health (e.g. doing exercise and avoiding over-drinking)

C 3 Science in a Sprint

Overview

Introduction

Sprinting is a relevant experience for students and involves plenty of science, in both the physical and biological domains. In this module, the familiar context of a sprint is used to demonstrate the laws and principles of mechanics in a sequence that is natural to the episode. In a sprint, the human body is viewed as a bio-machine with systems cooperating to enable effective movements. The physiology involved in providing sufficient energy for the sprint is also studied.

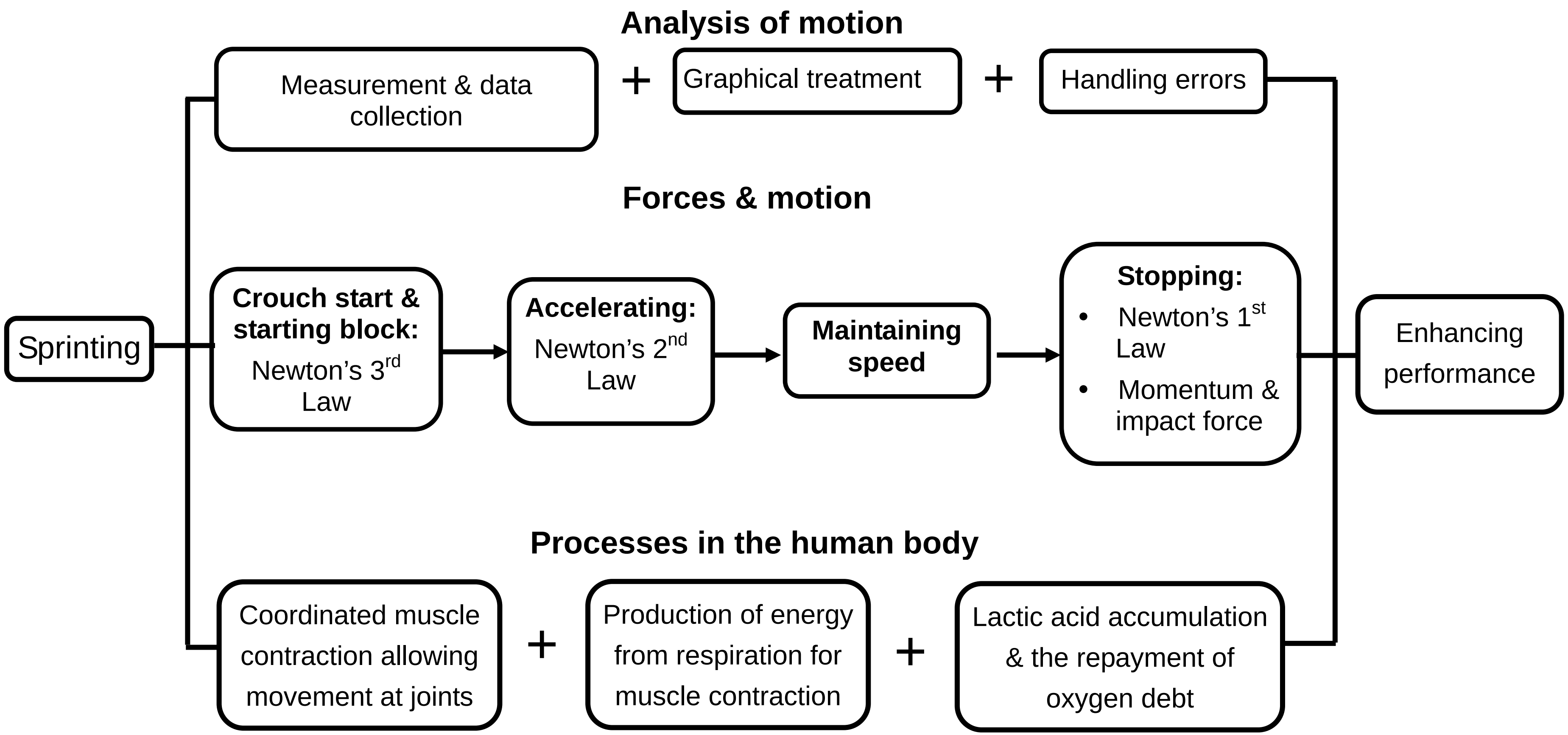
This topic focuses also on the measurement of the various parameters in a sprint. Measurements will inevitably incur errors and students are expected to deal with them sensibly. Students should also attempt to use a computer software to analyse the different stages of a sprint so that they can focus on the interpretation of graphs. In this way, they will come to see how advanced technology facilitates measurement with a greater degree of accuracy.

After studying this topic, students will be able to apply the laws and principles of mechanics to other areas of everyday life, not just in the context of a sprint. They will also come to appreciate the design of our body and the importance of training for improving performance.

Focusing Questions

- How do Newton's three Laws of Motion help us understand the motion of objects?
- How can we measure, describe and analyse motion?
- What is impact force? How can we reduce its magnitude during impact?
- How do our muscular and skeletal systems coordinate and work to bring about motion?
- How is energy produced in our body for sprinting?

Module Organisation



C 3: Science in a Sprint

Students should learn	Suggested learning and teaching activities
3.1 Forces and sprinting • Crouch start and starting block: Newton's 3rd Law • How to accelerate: Newton's 2nd Law • Maintaining speed – Centre of mass – Frictional force – Wind speed • After breaking the tape: inertia and Newton's 1st Law	• Watch video of a 100 metre race, observe carefully the motion of the sprinter at the different stages • Experience the different impulses produced at the starting blocks in crouch starts • Carry out various experiments to study Newton's Laws
3.2 Analysing a sprint • Analyse the motion of a sprinter – Retrieve data using a video-motion analysis software – *s-t*, *v-t* and *a-t* graphs – Interpret the meaning of slope and area under the graphs – Average speed – Equations of uniformly accelerated motion • Accuracy of time measurement – Starting signals, reaction time and its implications – Systematic and random errors – Fitting the best straight line in a graph – Use of advanced technology to reduce errors	• Use the video-motion analysis software to retrieve data for plotting s-t, v-t and a-t graphs • Analyse the motion of a sprinter with a video-motion analysis software • Measure distance, time and speed using data-loggers • Measure the time for a sprinter to complete a 100 metre race using different timing devices, identify any outliers and evaluate the accuracy of the timing devices • Discuss the difference in reaction time between time-keepers responding to the visual and sound signals given by the starter • Information search on modern devices for measuring time in international competitions
3.3 Impulse and impact force • Impulse and impact force: rate of change of momentum • Impact force and safety measures – Use of polypads in a 60 metre race for stopping – Qualitative treatment of the energy changes in inelastic collisions	• Watch a video of a 60 metre race and discuss the purposes of the installation of polypads at the end of the track • Carry out an experiment to demonstrate the effects of impact force during collision • Design a prototype air-cushioned sports shoe • Conduct an investigative study of sports

	shoes for different kinds of sports
3.4 Efficient movement in sprinting • The role of skeleton, skeletal muscles, tendons, ligaments and joints in movement • Differences in the degree of movement between a hinge joint and a ball-and-socket joint • The lever principle of movement • The action of opposing muscle pairs in movement • The relationship between the size and fibre content of muscles and muscle performance	• Examine a model of a human skeleton • Use models to demonstrate the ranges of movement permitted by a hinge joint and a ball-and-socket joint, and how muscles move appendages • Information search on how different exercises can improve muscle performance
3.5 Energy production for sprinting • Energy source in the skeletal muscle • Role of adenosine triphosphate (ATP) • Anaerobic respiration • Lactic acid accumulation and the repayment of oxygen debt	• Information search to find out whether carbohydrate loading is useful for a sprinter • Study the change in breathing rate during and after a sprint using a breath volume kit or data logger • Information search on the degree of dependence on anaerobic respiration of athletes performing sports other than sprinting
3.6 Enhancing performance • Training • Sports wear • Using drugs	• Experience the benefits of training with regard to the reduction of reaction time • Information search on incidents in which athletes were tested positive for performance-enhancing drugs and their consequences • Discuss the controversies of using drugs during training • Information search for the work of the anti-doping agency

Module highlights

In this module, students have opportunities to:

- recognise that accurately defining a system (e.g. the pair of action and reaction forces between a sprinter's foot and the starting block) helps us to describe the motion of the component parts

- appreciate that science is based on empirical evidence and that taking measurements is the prime means for analysing a motion
- recognise the existence of limitations of using a particular piece of equipment in making measurements and the importance of choosing an appropriate piece of equipment for making a specific measurement
- recognise that scientists take an average from repeated measurements to give a better estimate of the true value
- recognise that scientists draw up relationships between data collected (e.g. time and displacement) and make generalisations (e.g. mathematical equations relating velocity, acceleration and time) that help us to make predictions in new situations
- realise that scientists view the universe as a vast single system in which the basic rules are the same everywhere. As such, Newton's Laws are applicable in predicting the motion of objects on Earth as well as that in the universe
- realise that precise experimental design, proper instrumentation and honest reporting are important in the practice of science
- appreciate that the structure of different types of joints is related to the degree of movement each joint allows (form and function)
- realise that the skeleton and muscles in the human body are organised to provide the necessary lever systems for performing a sprint
- develop an awareness that scientific knowledge can be applied in enhancing athletic performance in an appropriate way or in an abused way
- appreciate the contribution of knowledge about motion to the design of products for protection (e.g. air-cushioned sports shoes, safety helmets)

C 4 Chemical Patterns

Overview

Introduction

At various times, scientists have tried to construct a systematic way of organising our understanding of elements by seeking patterns in the physical and chemical properties of the different elements. The modern periodic table that evolved is one of the greatest human endeavours. In addition to its practical use as an organiser, the periodic table also helps scientists to explain how the hundred elements can give rise to such a huge variety of chemical compounds. It was upon this platform that further explanations of key patterns in the behaviours of different materials were built, and predictions of chemical behaviour and the development of new materials were made easier.

By the end of Key Stage 3, students have been applying their understanding of particle theory to explain physical phenomena such as floating and sinking, and the expansion and contraction of substances. They know that the atom is the smallest unit of matter and that the atoms of some elements can join together to form compounds under some specific conditions. They have also encountered a variety of chemical reactions such as burning, neutralisation and the effect of acid rain on building materials.

In this module, students explore the world of matter in a new way. They begin to view basic knowledge of chemistry not only as useful information but also as the product of systematic inquiry. They are guided to live through the intellectual experience of seeking patterns through observations and analysis of evidence, and appreciate how reliable knowledge is generated.

This module also demonstrates how scientists at different times looked for conceptual tools that helped to make sense of the world. The two intertwined historical developments of the periodic table and the atomic model will be used to exemplify how major scientific breakthroughs may be built upon different lines of inquiry complementing and supplementing each other. Lastly, students are challenged to apply their understanding of these fundamental concepts of chemistry to predict and explain the formation of compounds and their properties at the microscopic level.

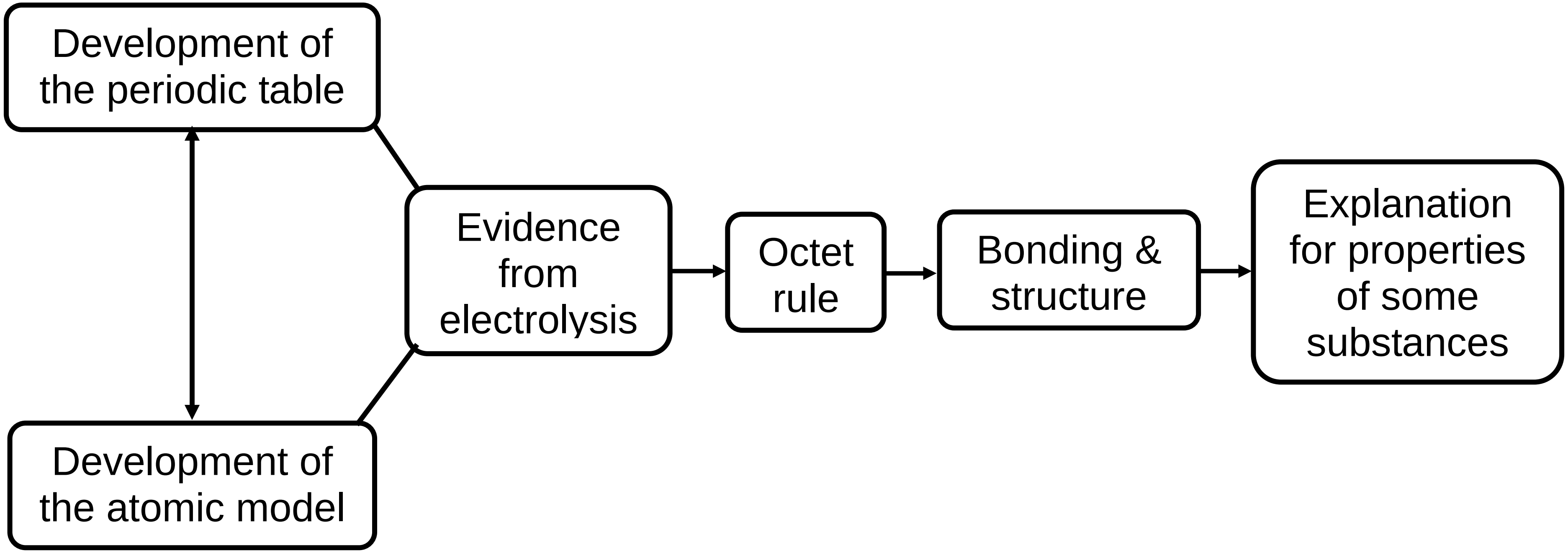
Focusing Questions

- What led scientists to look for patterns in the properties of elements and construct a systematic way of organising their understanding?
- How did our understanding of the structure of an atom lead to the refinement of the

periodic table?

- How could the patterns revealed in the periodic table be used in making predictions?
- Why do the properties of compounds differ so significantly with their elements?
- How are the properties of different substances explained by their structures and bondings?

Module Organisation



C 4: Chemical Patterns

Students should learn	Suggested learning and teaching activities
4.1 Elements in order • Brief history of different hypotheses on the nature of matter in different cultures • Alchemy and the study of matter • Work of Mendeleev and his predecessors on the empirical periodic table	• Search and compare the views of different philosophers on the nature of matter • Construct periodic tables by arranging elements in increasing melting point, boiling point and atomic mass • Discuss the kinds of problems scientists tried to solve by developing the periodic table
4.2 The periodic table • Features of the periodic table • Trends in physical and chemical properties of elements within groups I, VII and 0 • Comparison on reactivity between group I & group II metals	• Identify trends in the physical properties of elements within groups I, VII and 0 • Investigate the reactions of some metals with oxygen/air, water and dilute acids • Compare the reactivity of different halogens • Experiment to show the bleaching and disinfecting properties of chlorine • Information search on the practical uses of noble gases • Predict the chemical properties of unfamiliar elements in a group in the periodic table • Construct a mind map on patterns and trends identified in the periodic table
4.3 Looking into an atom • Democritus's idea of 'atom' • Development of the atomic model • Evidence in support of the atomic model • Relationships between protons, neutrons and electrons in an atom	• Black box experiment – determining the internal structure of a sealed wooden box • Search and present information on the development of the atomic model from Dalton's time to date • Simulate Rutherford's alpha-particle scattering experiment

4.4 Atomic number and the modern periodic table • Atomic number • Mass number • Isotopes • Electronic arrangements • Relationships between electronic arrangement and the chemical properties of the elements in Group I, VII and 0	• Study the ionisation energies of sodium and deduce its electronic arrangement • Identify relationship between the position of elements in the periodic table and their electronic arrangements • Write electronic arrangements for some atoms
4.5 Electrolysis and the ionic theory • Electrolysis as the decomposition of substances by electricity • Electrolysis providing evidence for the presence of ions • Cations and anions	• Electrolysis of molten lead bromide • Electrolysis of water in the presence of an acid to give hydrogen and oxygen • Experiment to show the migration of ions during electrolysis of potassium permanganate • Computer animation on the movement of ions during electrolysis • Draw a time line to describe 'Major events in scientists' journey to understanding matter'
4.6 Chemical bonding and structure • The tendency of atoms to achieve electronic configurations of the nearest noble gas in the periodic table (octet rule) • Chemical species: atom, ion, and molecule • Ionic bonding and structure exemplified by sodium chloride • Covalent bonding and simple molecular structure exemplified by water, oxygen and carbon dioxide • Giant covalent structure exemplified by diamond and graphite	• Draw electronic diagrams to represent atoms, ions and molecules • Predict the formation of ionic and covalent substances and write their chemical formulae • Draw electronic diagrams of ionic and simple molecular substances • Build models of ionic and simple molecular substances • Explain the properties of ionic substances by their structures • Explain the properties of simple molecular substances by their structures • Predict structures and properties of substances • Write balanced equations for the formation of simple ionic and covalent substances

Module highlights

In this module, students have opportunities to:

- appreciate that people at different times and in different cultures have always been seeking ways to make sense of the vast variety of matter existing around them (e.g. people in the East and the West proposed different frameworks for the 'basic elements' making up the world)
- recognise the periodic table as an organiser resulting from pattern seeking and logical thinking to organise our understanding of elements
- appreciate that scientists make use of patterns and trends to make predictions (e.g. predicting the chemical properties of unfamiliar elements based on trends revealed in the periodic table)
- develop skills in risk assessment in conducting experiments
- realise that discrepancies from patterns and trends (e.g. some elements did not fit into their expected positions in the periodic table constructed then) led scientists to further investigations and refinements of the periodic table
- appreciate that the atomic model (a conceptual model) is developed through systematic observations and much imagination (e.g. Rutherford's experiment)
- recognise the contribution of the atomic model to the development of the modern periodic table, to appreciate that scientific knowledge is a product of the collective wisdom of different scientists
- value the curiosity of scientists which drives them to scientific investigations (e.g. inference of the existence of ions through electrolysis, which shed light on the understanding of the structure of ionic compounds)
- recognise that scientists make generalisations (e.g. the octet rule) from observations to describe the behaviour of entities in a system
- appreciate that scientists developed symbols (e.g. chemical symbols), formulae and equations as concise languages to communicate in science
- recognise that matter is conserved and charges are balanced (constancy) in all chemical changes

C 5 Electrical Enlightenment

Overview

Introduction

Scientists of different nationalities contributed to the study of electricity and magnetism during the period 1800 – 1840. It started with a continuous and steady supply of current electricity from a chemical cell invented by the Italian scientist Volta in 1800. Two decades later, Oersted, a Danish scientist, serendipitously discovered that current could produce a magnetic effect. Ampere, a Frenchman, formulated and explained the relationship among current, magnetic field and force. This was an attempt by scientists to operationally define something that could not be seen and used simple mathematical equations to represent the interrelationships, making predictions of cause-effect relationships between electricity and magnetism possible. In 1831, the great British experimenter, Faraday, discovered electromagnetic induction, which led to large-scale generation of electricity from mechanical energy.

From then onwards, we moved from the age of discovery to invention as we were able to harness electricity and magnetism. Students should find the stories of inventions, such as that of Bell, Edison and Marconi, stimulating. In the new millennium scientists are still working hard with the quest for superconductors that are viable for commercial uses.

In this module, a historical approach is adopted to lead students to revisit the work of pioneers in electricity and magnetism. By repeating their experiments, students will come to appreciate the importance of experimentation in the advancement of science. Students are expected to learn electricity and magnetism from a perspective which relates the significance of the discoveries and the state-of-the-art applications.

Focusing Questions

- What is the basic principle of chemical cells? What drives charges to circulate in a circuit?
- How is the interaction between electricity and magnetism utilised to generate mechanical energy?
- What determines the magnitude of the current in an electric circuit?
- What is electromagnetic induction, and how do we generate electrical energy from mechanical work?
- How do we harness electrical energy to other forms? How can electricity be used safely at home?

- What is the significance of experimentation in the study of electricity and magnetism and the subsequent development from discoveries to inventions?

Module Organisation

Timeline	Pioneer	Major discovery	Significance	Implications & applications
1800	**Volta** *Italian*	• Electricity from chemical reaction	• Stable supply of current that allows a leap from electrostatics to current electricity • Electrolysis	• Chemical cell • Fuel cell
1820	**Oersted** *Danish*	• Magnetic effect of a current	• The first time in history that we knew magnetism can be produced from electricity	
	Ampere *French*	• Solenoid • Force on current-carrying conductor in a magnetic field	• The birth of electromagnetism	• EM waves • Telecommunication
1821	**Faraday** *British*	• Electromagnetic rotation	• Electricity can be harnessed to drive machines, i.e. from electrical energy to mechanical energy	• Motor
1827	**Ohm** *German*	• Ohm's Law • Heating effect of current	• The relationship between current and voltage in a circuit	• Fuse • Quest for superconductor
1831	**Faraday** *British*	• Electromagnetic induction	• Conversion of mechanical energy to electrical energy • a.c. electricity	• Generator • Long distance transmission of electricity • EM waves • Telecommunication
1840	**Joule** *British*	• Conservation of electrical energy	• Quantifying electrical energy • Electricity consumption	• Domestic electricity

C 5: Electrical Enlightenment

Students should learn	Suggested learning and teaching activities
5.1 Volta and the chemical cell	
• Volta's discovery of producing electric current from chemical reactions in 1800 • Basic structure of a simple chemical cell • Reactions that occur at the electrodes in simple chemical cells • Redox reaction as the basic principle of chemical cells • Working principles and implications of fuel cells	• Repeat Volta's experiment to make a voltaic cell • Make simple chemical cells and compare their voltages • Write ionic half equations for reactions that occur at the electrodes in simple chemical cells • Examine different types of batteries (e.g. alkaline, mercury, Li-ion, Ni-Cd batteries, lead acid accumulator) • Search and present information on the prospect of fuel cells
5.2 The development of electrolysis	
• The first decomposition of water by electricity in 1800 • Applications of electrolysis: decomposition of substances, purification of metal and electroplating	• Read about Davy's discovery of sodium, magnesium, calcium through electrolysis in the early 19^{th} century • Search for information on industrial extraction of aluminium by electrolysis and the recycling of aluminium • Electroplating experiments (e.g. electroplating a key with copper or nickel)
5.3 The work of Oersted and Ampere	
• Oersted's discovery of the magnetic effect of a current in 1820 • Right hand grip rule • Ampere's investigation of current and magnetism after Oersted's discovery: invention of solenoid	• Repeat Oersted's experiment which led him to discover the magnetic effect of a current • Make a solenoid (electromagnet) and investigate its magnetic effect • Repeat Ampere's experiment in studying the force between two parallel current-carrying wires • Dismantle a moving coil type loudspeaker to find out how it works

5.4 Ohm’s contribution to current electricity	
• Ohm’s discovery of the resistance to current in a wire and the study of the relationship among voltage, current and resistance in 1827 • Ohm’s Law • Circuit components of a simple circuit and simple circuit diagram • Measurement of voltage and current using voltmeters and ammeters; reading resistance from V-I graph • Variable resistor (rheostat) and its use in controlling the current in a circuit	• Propose analogies of voltage, current and resistance in electrical circuits (e.g. water flow and transport of cargo) and discuss the inadequacies of the analogies • Repeat Ohm’s investigation of the relationship among voltage, current and resistance • Propose a model using the particle theory to explain the different resistance to current in different wires • Measure resistance of ohmic and non-ohmic resistors (e.g. bulb) and plot their V-I graphs
5.5 The great experimenter: Faraday	
• Faraday’s discovery of electromagnetic rotation in 1821 • Turning effect of a current-carrying coil in a magnetic field • Working principle of a simple d.c. motor • Faraday’s discovery of electromagnetic induction in 1831 • Factors affecting the magnitude of induced voltage • Working principle of a simple a.c. generator	• Repeat Faraday’s experiment on electromagnetic rotation (a current-carrying wire suspended in a magnetic field and dipped into a dish of mercury) • Make a simple d.c. motor • Investigate factors affecting induced voltage • Study the current production of an a.c. generator with a light bulb or C.R.O. display • Read about Bell’s invention of the telephone in 1876, Hertz’s invention of a device to send and receive electromagnetic waves in 1887, and Marconi’s invention of radio in 1895 • Search for articles about the epoch making developments in telecommunications (e.g. mobile phone and world wide web)
5.6 Joule and the consumption of electricity	
• Joule’s discovery of energy conservation in electrical circuits and establishment of Joule’s Law in 1840 • Electrical energy = I^2Rt • The quest for high temperature	• Measure electrical energy with a joulemeter • Study the heating effect of a current in a nichrome wire • Propose a model using the particle

superconductors	theory to explain the heating effect of a current-carrying wire • Read about the contribution of Paul Chu to the development of high-temperature superconductor • Search for information on the advances in Maglev trains
5.7 Domestic electricity • Live, neutral and earth wires in the mains circuit • Connection of electrical appliances to the mains in ring circuits • Safe use of electricity • Overloaded circuits and short circuits • The use of fuses and circuit breakers to prevent fire due to electrical faults	• Examine plugs, sockets and adapters and electricians' 'live' probe • Search for updated information about the Electrical Ordinances • Read the specifications of an electrical appliance • Read about Edison's invention of an incandescent lamp in 1879

Module highlights

In this module, students have opportunities to

- appreciate that matter is conserved in the system in electrolysis
- recognise ionic equations as a concise language for describing changes at electrodes during electrolysis
- appreciate the scientist's habit of mind which prompted Oersted to design experiments for exploring the unexpected magnetic effect of a current
- appreciate that models have limitations (e.g. conceptualising electric current as flow of water may mislead people to think of electricity as material flow)
- appreciate that systems, and sub-systems, can interact and influence each other, and change in response to external changes (e.g. the current changes in a circuit when the resistance of a variable resistor changes)
- realise that proper instrumentation and careful qualitative and quantitative analyses of experimental data, which are essential in the practice of science, allowed Faraday to make many discoveries in electricity, magnetism and electrochemistry
- realise that scientists may not work from observations but from tentative hypotheses (e.g. the belief in conservation of energy led Faraday to carry out experiments that confirmed his idea of electromagnetic induction)
- appreciate that the development of electricity and magnetism is contributed to by the free exchange of ideas, open-minded discussion and debate among scientists
- appreciate that the knowledge of electricity is applied to make inventions that transform the daily life of human beings
- recognise and appreciate that some electromagnetic components (e.g. loudspeaker and microphone) are designed in a form that achieves a particular function

C 6 Balance in Nature

Overview

Introduction

Nature can be considered as a big system comprising numerous small systems. The balance of Nature that is so crucial to our survival is dependent on the regulation and interaction within and among its different components.

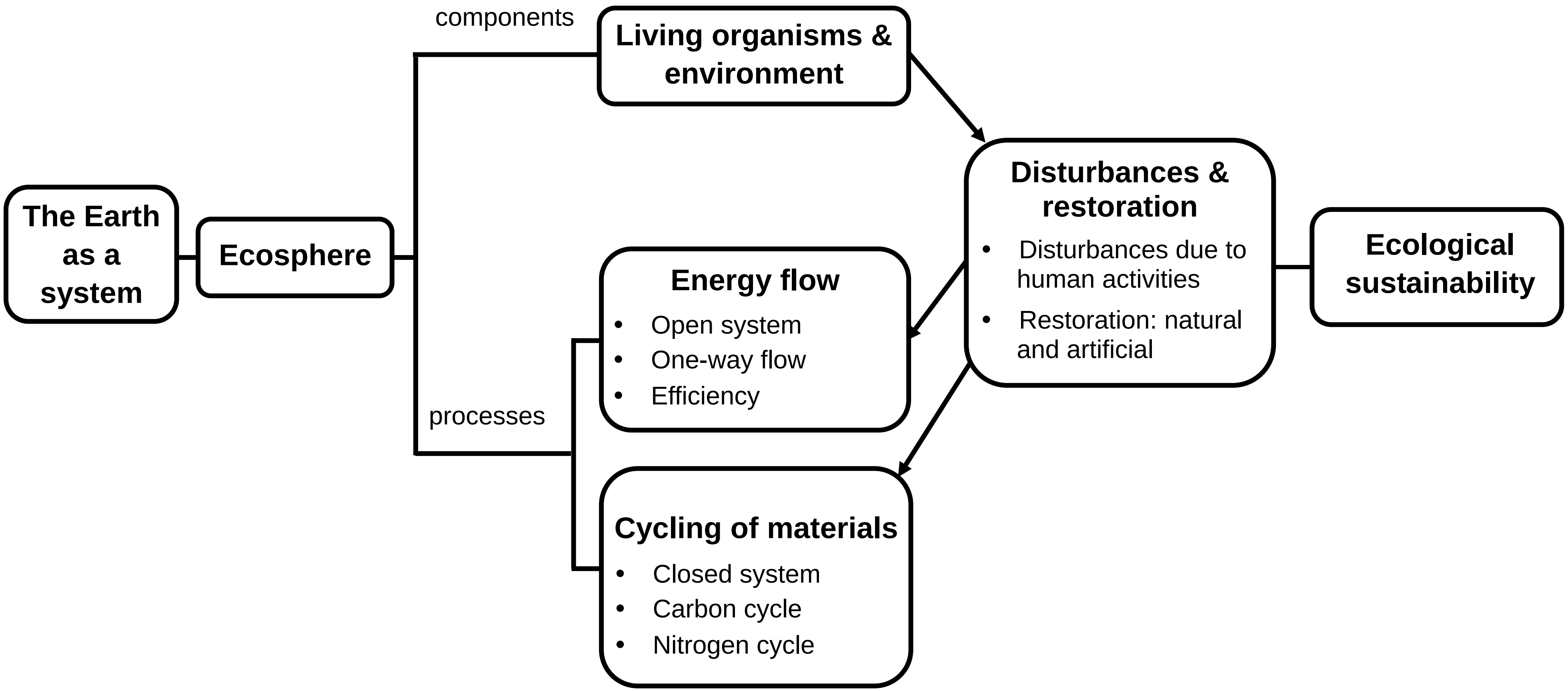
In this module, ecosystems are used to illustrate how self-regulation plays an important role in maintaining equilibrium among complex interactions between different kinds of living organisms and their non-living environment. The concepts of cycling of materials and the flow of energy within ecosystems are also discussed.

Nature has an ability to restore equilibrium when its balance is upset by natural or human disturbances (e.g. forest fire, exploitation of resources). However, human activities can be very devastating and bring irreversible and negative changes in Nature. In this module, students learn to become more aware of the importance of balance in Nature and how human activities should be regulated to maintain ecological sustainability for the survival of human kind.

Focusing Questions

- How does energy flow in the ecosphere? How do the first and second laws of thermodynamics help to explain energy flow in an ecosphere?
- What are biogeochemical cycles, and why are they important to the balance in Nature?
- How do natural disasters and human activities upset the balance in Nature and how can the balance be restored?
- What are the key issues that we must address in order to attain sustainable development?

Module Organisation



C 6: Balance in Nature

Students should learn	Suggested learning and teaching activities
6.1 The Earth as a system • Spheres of the Earth: atmosphere, hydrosphere, lithosphere, biosphere and ecosphere • The Gaia hypothesis	• Watch videos on how people obtain useful materials from the atmosphere, hydrosphere and lithosphere (e.g. fractional distillation of liquid air, electrolysis of sea water and extraction of metals) • Information search on the major elements and compounds found in the different spheres. • Discuss the validity of the Gaia hypothesis
6.2 Energy flow in the ecosphere • Converting light energy into biologically usable energy: photosynthesis • The one-way flow of energy: food chains, food webs and ecological pyramids • The first and second laws of thermodynamics in explaining energy flow • Biological productivity and efficiency of energy transfer between trophic levels	• Construct and interpret pyramids of numbers, pyramids of biomass and pyramids of energy • Information search for a list of animals and plants for a chosen habitat, find out as many food chains as possible and construct a food web using these food chains
6.3 Cycling of materials in the ecosphere • Biogeochemical cycles: chemical form, reservoirs, rates of transfer, pathways, cycles and energy involved • The carbon cycle • The nitrogen cycle • The important role of decomposers in the cycling of materials	• Interpret flow charts describing how carbon and nitrogen cycle between the spheres of the Earth • Use audio-visual materials to illustrate the nitrogen cycle and the carbon cycle • Make compost in school • Make an ecosphere
6.4 Disturbances and restoration	

• Ecological succession in the restoration and recovery of damaged lands • Effects of human activities on the ecosystems: – Algal bloom due to chemical fertilisers and domestic sewage – Bioaccumulation of heavy metals – Global warming due to the overuse of fossil fuels and deforestation – Reduction in biodiversity due to human activities • Artificial restoration and its costs	• Use audio-visual materials to show examples of ecological succession • Observe the colonisation of wastelands and hillsides after a fire • Observe different types of vegetation communities in the uplands of Hong Kong to illustrate the transitional stages in succession. • Information search for evidence on global warming and El Nino, and the possible causes • Discuss about the importance of biodiversity • Watch videos on different habitats to illustrate biodiversity • Read about artificial reef as a means for artificial restoration
6.5 The hunt for balance • Resource management: demand and supply of natural resources (e.g. minerals, forest and energy) • Environmental Protection – Pollution Control at the source (e.g. efficiency enhancement, and emission reduction) – Integrated waste management (IWM) that include reuse, reduce, recycle, remediate, landfill and incineration • Economic development and ecological sustainability	• Information search on strategies of pollution control: 'dilute and disperse' and 'concentrate and contain' • Information search on the popularity of the various waste management methods in Hong Kong • Debate on the dilemma between urbanisation, industrialisation and conservation • Exploring the development of biofuel • Making biodiesel

Module highlights

In this module, students have opportunities to:

- Appreciate that the Earth is a single big system comprising numerous sub-systems interacting with each other to maintain the well-being of living things
- appreciate that the Gaia hypothesis provides a conceptual model for viewing the Earth as a single system in which all things are interconnected
- recognise the ecosphere as an open system into which energy from the Sun flows
- realise the order of one-way flow of energy among the living organisms on Earth
- use flow diagrams to illustrate the cycling of materials among the spheres of the Earth
- realise that matter exists in different chemical forms when cycling among the spheres of the Earth

- recognise the ecosphere as a closed system within which matter is conserved in the biogeochemical cycles
- realise that balance in Nature is dynamic and the equilibrium is determined by the relative rates of change of the processes of disturbances and restoration
- develop an awareness that local ecological and environmental problems may have amplified effects elsewhere in the world
- appreciate the efforts scientists put into research for conserving natural resources (e.g. development of biofuels)
- reflect on one's own values and evaluate those of others in appraising issues such as the global environment, the use of resources and the related consequences etc.
- employ cost-benefit-risk assessment in technological and environmental issues
- evaluate the role of individuals and groups in influencing decision-making on a sustainable future
- develop a respect for Nature and a concern for the sustainable development of the Earth
- develop a commitment to contribute to the betterment of the local and global environment

C 7 Radiation and Us

Overview

Introduction

Radiation mainly refers to the various kinds of waves in the electromagnetic spectrum and to the α- and β- particles emitted during radioactive decay. Both areas are addressed in this module.

In this module, the parameters commonly used to describe radiation as energy that travels as waves are introduced. Radiation is emitted by a source and travels in a straight line until it hits another object. Because of its invisibility (except visible light), we can only infer its presence from its interaction with matter. The increasing application of radiation in daily commodities (e.g. the microwave oven and mobile phone) has raised people's concern about radiation safety. An understanding of the interaction of radiation with matter will help students to comprehend media coverage on the health risks posed by different sorts of radiation. They will then be more able to decide on how well founded the media reports are and understand why there is so much controversy in this area.

Students also learn about radioactive substances and the ionising radiation they emit. Through understanding the properties of these radiations, and the effects they have on our body, students learn to assess the effects of radioactivity and participate in discourse about use, storage, disposal and safety measures associated with using radioactive substances.

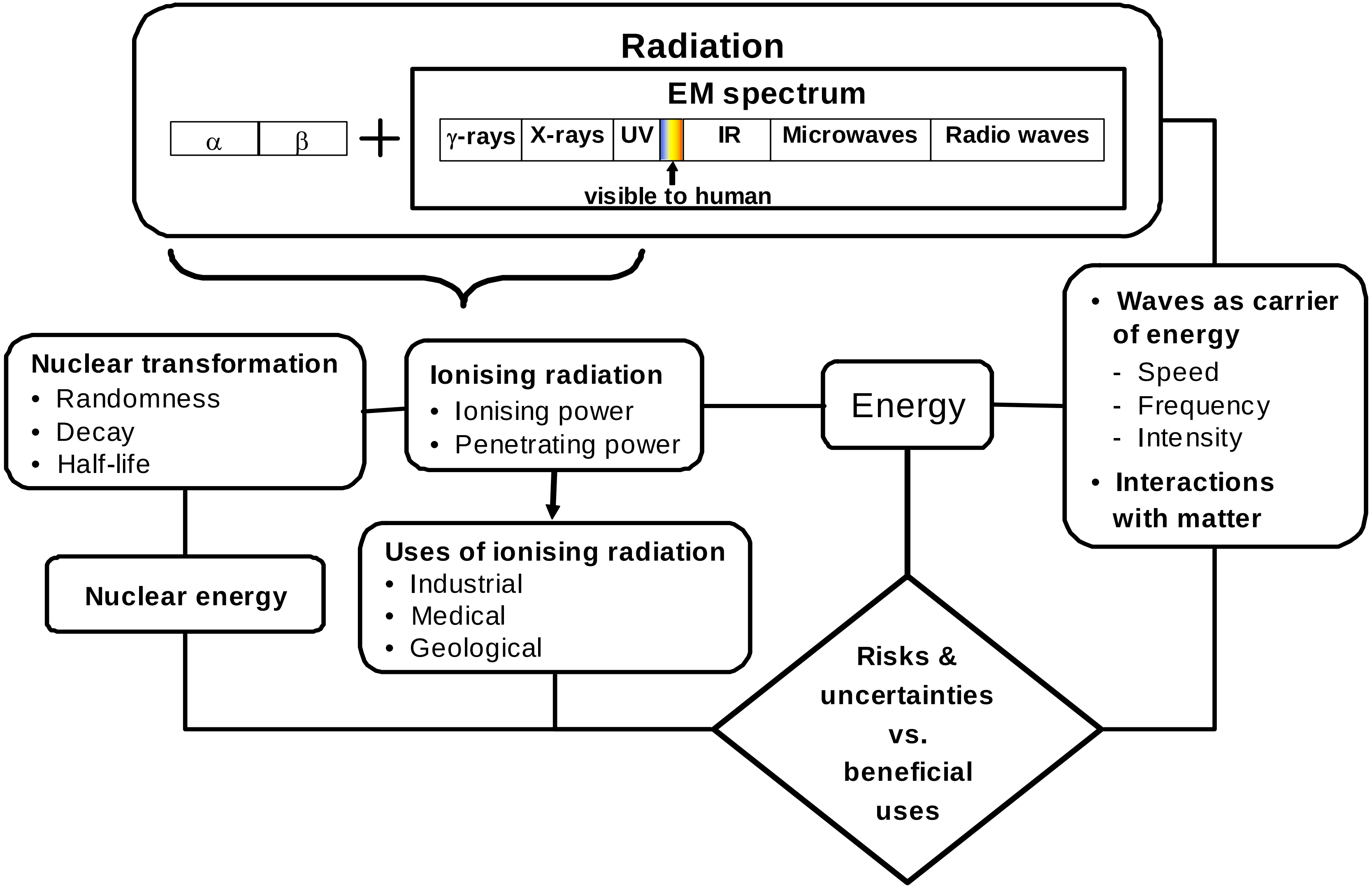
In putting scientific knowledge to use in everyday situations, public opinion can vary from the highly conservative (keeping the status quo) to the highly adventurous. Students will experience such uncertainties in analysing case studies related to radiation and radioactivity. Students should appreciate that scientific conclusions are based on empirical evidence collected during investigations and there is no absolute certainty in the answers. They will also realise the importance of distinguishing evidence from myth, weighing risks against benefits, and see that an understanding of the science which lies behind such issues is important in helping them to make informed decisions.

Focusing Questions

- What are the different types of EM radiation and what happens when these radiations interact with matter?
- In what ways can EM radiations harm living tissues?
- What are ionising radiations and their properties? What are their possible health hazards?

- How can radioactive materials be used and handled safely, including waste?
- How can we tap energy for use from nuclear reactions?
- What are the uncertainties involved in decisions about the use of radiations?

Module Organisation



C 7: Radiation and Us

Students should learn	Suggested learning and teaching activities
7.1 The electromagnetic spectrum • A descriptive outline of the electromagnetic spectrum • Approximate wavelength ranges of γ-rays, X-rays, ultraviolet, visible, infrared, microwaves, radio waves • The wave nature of EM radiation • Ways of representing EM radiation • The relationship between frequency, wavelength and wave speed ($c = f\lambda$)	• Use a long spring to demonstrate the propagation, reflection and interference of waves • Read about Maxwell's formulation of the concept of electromagnetic waves • Repeat Hertz's experiment in sending a spark across a room
7.2 EM radiation as a carrier of energy • EM radiation delivers energy in 'packets' called photons (energy = constant × frequency) • Energy of a beam of EM radiation (number of photons × energy per photon) • Intensity of radiation and its variation with distance from the source • The flame test as an example for producing radiation of a particular frequency by atomic emission • The reflection, absorption and transmission of EM radiation (e.g. microwaves) • Applications and risks of EM radiation as exemplified by UV radiation (e.g. sterilisation, material identification, sun burns, photochemical smog) • The benefits and risks of using EM radiation in everyday life	• Investigate the relationship between the size of the light patch on the wall and its distance from the source • Perform a flame test of several metal salts • Investigations on the reflection, absorption and transmission of microwaves • Information search on the maintenance of ozone layer • Case study of controversial issues related to the use of EM radiation (e.g. Are mobile phones a health risk? Is the use of intensified pulse light in beauty therapy safe? Are the claims of the therapeutic benefits of an infrared bed mattress trustworthy?)
7.3 Ionising radiations • High energy EM radiation (e.g. high frequency UV, X-rays and γ-rays) can ionise atoms • The three types of nuclear radiation: α, β and γ radiations – The origin and detection of nuclear radiation	• History of the discovery of the ionising radiations • Use of Geiger-Muller counters in investigating background radiation • Experiment to compare the penetrating power of α, β and γ radiations

– Compare the penetrating power, range in air and ionising power of α, β and γ radiations – eV as a unit of energy	
7.4 The decay, half-life and uses of radioisotopes • Random nature of decay • Decay series • Determining the half-life from a decay-curve • Uses of radioisotopes: industrial, medical and dating • Radiation safety – Effects of α, β and γ radiations on us – Background radiation – The ALARA (as low as reasonably achievable) principle – Radiation dose in sievert (Sv) • Risk-benefit assessment on the diagnostic and therapeutic uses of radioisotopes	• Using coins and dice to model the decay of nuclei • Investigation on indoor radon concentration and the factors which lead to an increase in concentration • Information search on radioactive tracers and other uses of radioisotopes in medicine, agriculture, industry (e.g. food irradiation and product sterilisation) • Case study – benefits and risks related to diagnostic and therapeutic uses of radioisotopes • Activity on calculating the risks and benefits for making an informed decision • Information search on the use of film badges and TLD in monitoring dosages • Information search on how a smoke detector works and what arrangements should be made for the disposal of a smoke detector.
7.5 Nuclear energy • Fission and fusion reactions • Nuclear energy generation: $E = mc^2$ • Proper disposal of nuclear waste	• Watch a video on how Einstein came to the equation $E = mc^2$ • Information search on nuclear accidents, e.g. the Chernobyl accident • Compare the generation of electrical power using nuclear fission and the burning of fossil fuels • Take a tour of a virtual nuclear reactor

Module highlights

In this module, students have opportunities to:

- value the role and contribution of science in our understanding of phenomena involving EM radiation that are not directly observable
- realise that scientists formulate theories and put forward models to explain observed phenomena (e.g. the use of the atomic model in explaining the difference in flame colours in flame tests)

- appreciate the contribution of the applications of EM radiation in research, medical and industrial fields
- recognise that radioactive decay is an illustration that substances in Nature may experience spontaneous change
- recognise that the half-life of any particular isotope, being constant and unaffected by physical conditions, is useful for dating
- appreciate the ideas of conservation of matter and conservation of energy in studying radioactive decay
- appreciate that the theory $E = mc^2$, though developed from an intelligent 'thought experience' of Einstein, has established its rigour by experimental confirmation and its ability to make predictions about the interchange of mass and energy in a nuclear reactor
- develop an awareness of, and respect for, different points of view in society on controversial issues (e.g. generating electricity using nuclear energy)
- develop an ability to interpret and evaluate information presented in survey reports and media reports.
- develop the skills for making risk-benefit analysis in considering the use of radioactive decay in medical diagnosis and therapies, and in generating electricity

C 8 From Genes to Life

Overview

Introduction

One major feature distinguishing living organisms from non-living things is the ability to pass genetic information from generation to generation. The inherited genetic information plays a critical role in controlling life phenomena.

In this module, students learn that DNA can replicate (make a copy of itself) before cell division so that genetic information can be passed to the next generation. The fundamental process of genetic information flow (i.e. from DNA to RNA then to proteins) is introduced. An understanding of this process allows students to appreciate how proteins essential in different aspects of life processes are produced. A few genetic diseases are briefly discussed to show how defects in genetic information lead to congenital abnormalities.

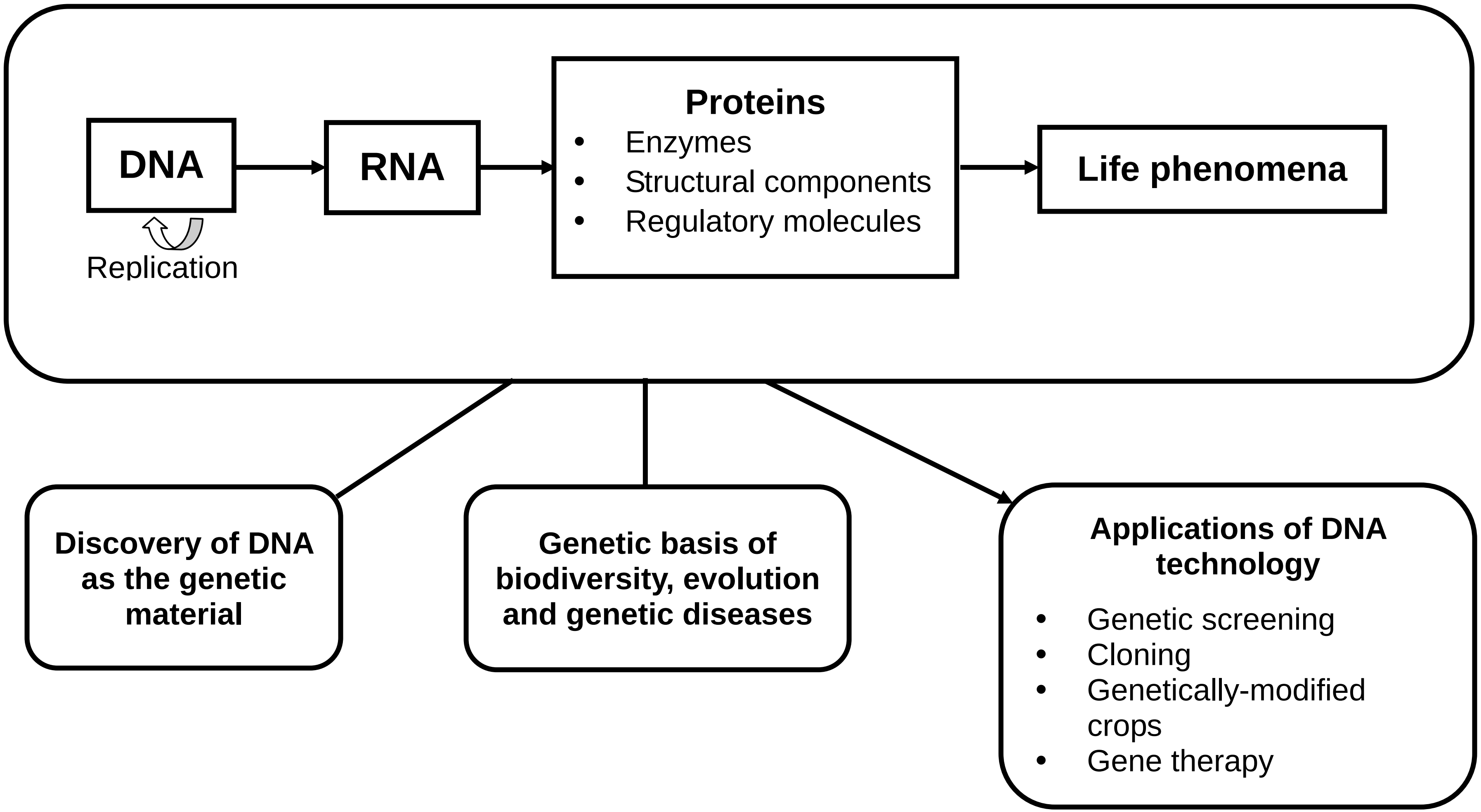
The discoveries of DNA as the genetic material and of its double helix structure laid the cornerstone of genetics. In this module, students will appreciate these scientific endeavours by examining the work of great scientists and, in the process, realise that innovative interpretation of experimental data is one of the keys for great science. In addition, Mendel's deduction of Laws of Inheritance is a good illustration of how scientists work – making hypotheses, verifying them through careful experimental design and analysis of experimental results, and drawing valid conclusions.

The development of gene technology has revolutionised our society. One of the aims of this module is to promote students' understanding in gene technology so that they can evaluate its applications (e.g. genetic screening, cloning, production of genetically modified crops, and gene therapy).

Focusing Questions

- How did we come to know that DNA is the carrier of genetic information and how was its structure discovered?
- How does the structure of DNA enable it to serve as a carrier of genetic information and how do genes on the DNA control life phenomena?
- What is the significance of Mendel's work and what contributed to his success?
- How does our knowledge of genes help us to understand the basis of biodiversity, evolution and genetic diseases?
- What are the applications of DNA technology? What are the ethical, economic and social implications of these applications?

Module Organisation



Suggested Teaching Sequences

Sequence A

1. Case studies on family history of genetic diseases / the use of DNA fingerprinting in forensic science (e.g. parentage testing)
2. Inheritance and chromosomes
3. Patterns of inheritance
4. Chemical nature of genes
5. Relationship between genes, amino acids and proteins
6. Mutations and variations
7. Applications of DNA technology

Sequence B

1. Importance of proteins
2. Relationship between chromosomes, DNA and genes
3. From genes to proteins
4. Inheritance and chromosomes
5. Patterns of inheritance
6. Mutations and variations
7. Applications of DNA technology

Sequence C

1. Genetic information flow that controls life phenomena (DNA → DNA; DNA → RNA → protein; proteins → life phenomena)
2. DNA as the genetic material (Historical approach)
3. Genetic basis of biodiversity, evolution, and genetic diseases
4. Applications of DNA technology

C 8: From Genes to Life

Students should learn	Suggested learning and teaching activities
8.1 Genetic information flow that controls life phenomena	
• The relationship between the structure of DNA and genetic information flow • Transmission of genetic information to the next generation: replication of DNA • Expression of genetic information to control life phenomena – DNA molecules passing their information to mRNA molecules – Decoding information in mRNA to produce protein molecules for various life processes	• Using the DNA spooling method to extract DNA from living materials (e.g. onion and fish testes) • Watch animations of the processes of genetic information flow • Decode a DNA sequence • Discuss the roles of proteins in our body: acting as enzymes, structural components and regulatory molecules
8.2 DNA as the genetic material	
• Evidence which suggests DNA is the genetic material • The double helix model for DNA molecules: evidence contributing to its construction; structural features enabling DNA to serve as a genetic carrier • Deduction of Mendel's Laws of Inheritance from findings on monohybrid and dihybrid inheritance • Mitosis, meiosis, and chromosomal theory as the physical basis of Mendel's Laws	• Information search on the experiments suggesting DNA is the genetic material and the discovery of the DNA structure • Discuss how the work of physicists, chemists and biologists have contributed to our current knowledge on DNA • Build a model of a double helix DNA molecule • Read about Mendel's work • Carry out virtual experiments on monohybrid and dihybrid inheritance • Use animations/films to show mitosis, meiosis and the coiling of DNA into chromosomes • Use electron micrographs to show mitosis, meiosis, and chromosomes
8.3 Genetic basis of biodiversity, evolution, and genetic diseases	
• Factors contributing to variations between individuals within a species • Genetic variations and the claim of evolution by natural selection • Gene mutation and its possible effects (e.g. sickle-celled anemia) • Chromosome mutation and its possible effects (e.g. Down syndrome)	• Using computer modelling to simulate evolution by natural selection • Use the development of resistance in bacteria to certain antibiotics as an example to illustrate the claim of an evolutionary mechanism • Activity to pair up chromosomes to show the typical chromosome pattern in

• Spontaneous and induced mutations	Down syndrome • Examine photomicrographs of chromosome mutation • Discuss the precautionary measures in using X-rays in medical examinations
8.4 Applications of DNA technology • Recombinant DNA technology: basic principle and its applications in gene cloning (e.g. production of insulin in *E. coli*); gene therapy and production of genetically-modified crops • DNA fingerprinting: applications in forensic science, parentage testing and diagnosis of genetic diseases • Organism cloning • The impact of the Human Genome Project on our society	• Carry out separation of digested DNA molecules by electrophoresis • Using paper models to simulate the process of making recombinant DNA • Use animations to illustrate the process of recombinant DNA technology • Read about how the sheep Dolly was cloned • Discuss the ethical, social and legal impact of biotechnology on society • Discuss the limitations of the application of DNA fingerprinting in forensic science

Module highlights

In this module, students have opportunities to:

- appreciate that the cell is a highly organised entity in which nucleotides, DNA and chromosomes are at different levels of organisation
- recognise the specific order of the flow of genetic information from DNA to mRNA to protein
- appreciate that scientific theories evolve with new evidence (e.g. scientists came to refute protein as the genetic material when emerging experimental evidence pointed to DNA)
- appreciate the importance of imagination in theorising, as scientific theories do not emerge automatically from data and its analysis alone (e.g. Mendel suggesting the Laws of Inheritance well before the existence of genes was realised; Watson and Crick proposing the anti-parallel double helical structure of DNA)
- appreciate that the work of scientists in one field may contribute to development of ideas in another (e.g. Watson and Crick drew upon evidence worked out by scientists in different fields to build their hypothesis of the double helical structure of DNA)
- appreciate that the different sequencing of the bases of the nucleotides in the DNA molecules is the basis of biodiversity
- appreciate that scientific knowledge is generated from a systematic process: making hypotheses, verifying them through careful experimental design and analyses of experimental results, and drawing valid conclusions (e.g. Mendel's deduction of Laws of Inheritance from carefully designed experiments)
- recognise that the constancy in chromosome number in a fertilised egg is maintained by meiosis in gamete formation; and that mutation may change the number of chromosomes in the gamete and hence lead to abnormalities in offspring (e.g. Down syndrome)

- appreciate that though it can be induced or enhanced by mutagens, mutation occurs spontaneously in Nature
- develop the skills for making risk-benefit analysis in weighing the benefits of using nuclear radiation in medical diagnosis and therapy against the mutagenic effects of radiation to the body cells
- appreciate that science has its limitations and cannot always provide clear-cut answers in certain areas, such as the moral issues surrounding DNA technology
- realise that the direction of scientific research is affected by prevailing opinions in society and its culture (e.g. research using human embryos is allowed in some countries but not in others)
- develop a concern for issues relating to the applications of DNA technology in different fields
- realise the social impact of the swift advances in DNA technology which may affect one's personal decisions
- appreciate the importance of the joint effort of scientists all over the world and peer review for the rapid achievements in the Human Genome Project

Elective Part

(E1-E3)

2.3.4 Elective Part

E 1 Energy, Weather and Air Quality

Overview

Introduction

The Earth is the only planet known to have living organisms. The interactions between the energy from the Sun and the Earth's atmosphere keep the Earth warm enough for organisms to live in. The unlocking of the energy stored in fossil fuels to make fire and later to generate energy for domestic and industrial uses has greatly improved the quality of life. Our consumption of energy plays an important role in the Earth's energy budget.

The incoming solar energy is the driving force behind weather phenomena, and temperature, pressure and humidity are all linked to it. Weather affects not only our everyday activities but also the air quality in urbanised areas. It plays a part in the dispersion and stagnation of the air pollutants emitted by power generation plants and vehicles.

In this module, students study the atmosphere and the basic elements of weather. They are introduced to weather maps and how weather forecasts are made. The effects of Hong Kong's distinctive location, topography, and weather patterns on the daily and seasonal variation of air quality are discussed. Students also consider the origins of air pollutants, some means to reduce their emission and the significance of the air pollution index.

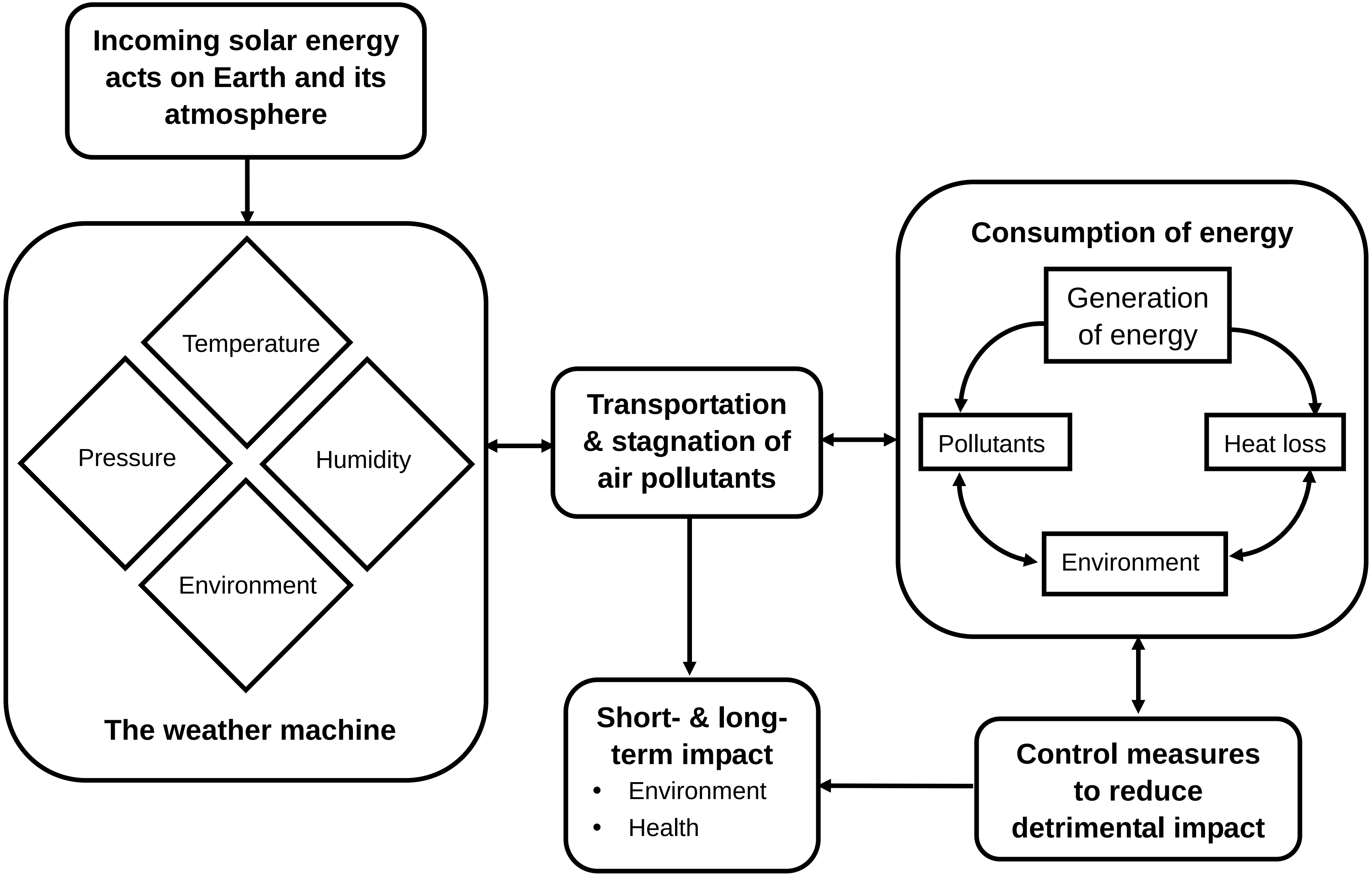
On completing this module, students will recognise the long-term effects of human-induced environmental changes due to the use of energy and relevant societal issues. Also, they will appreciate that, though the effects of weather and local topography on air quality are beyond our control, there are still many measures we can take to help improve air quality.

Focusing Questions

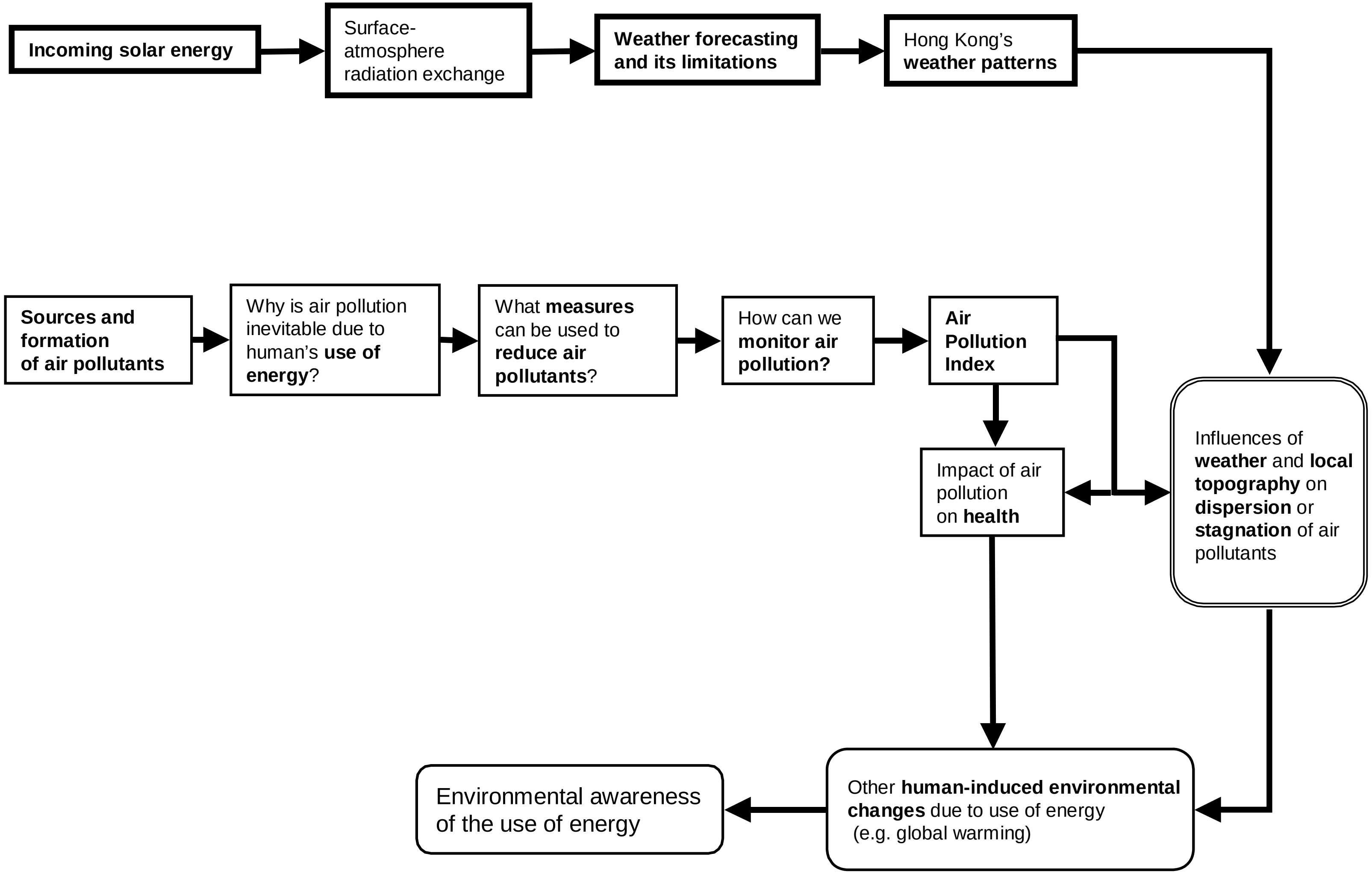
- How is the Earth kept warm?
- What are the basic elements of weather? How do we comprehend some weather systems and phenomena through understanding the basic elements of weather?
- What is weather forecasting and how are weather forecasts made?
- What are the common weather patterns in Hong Kong? How are our atmospheric conditions affected by human activities?
- What are air pollutants and what are their origins? Why is air pollution harmful to us and to the environment?
- How are the transportation and stagnation of air pollutants influenced by weather and local topography?
- How does the use of energy affect our environment and what choices can we make

personally, locally, or globally to improve air quality?

Module Organisation



Suggested Teaching Sequence



E 1: Energy, Weather and Air Quality

<table>
<tr><th>Students should learn</th><th>Suggested learning and teaching activities</th></tr>
<tr><td>

1.1 Solar energy and the Earth's atmosphere

- The composition of the atmosphere
- The influence of water vapour, carbon dioxide and ozone on weather
- Balancing act of the atmosphere
  - Absorption and reflection of incoming solar radiation
  - Surface-atmosphere radiation exchange
  - The role of water vapour, carbon dioxide and infra-red radiation in the atmospheric greenhouse effect
- Layers of the atmosphere
  - The troposphere, tropopause and stratosphere
  - Thermal structure of the atmosphere and stability

</td><td>

- Investigate the different heat transfer mechanisms: conduction, convection and radiation
- Computer simulation of the surface-atmosphere radiation exchange
- Demonstrate stability in the atmosphere by heating water at different heights in a water tank
- Experiments to illustrate the water cycle
- Measure the specific latent heat of vaporisation of water

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1.2 The weather machine

- The major atmospheric parameters: temperature, pressure, humidity
- Temperature factor:
  - Specific heat capacity and thermal characteristics of land and sea
  - Seasonal and diurnal variation of temperature
- Temperature-volume relationship: an air parcel expands on heating and contracts on cooling
- Volume-pressure relationship: the pressure of an air parcel decreases as it expands and increases as it contracts
- Atmospheric pressure and wind
  - Gravity and vertical variation of atmospheric pressure
  - Pressure gradient and wind flow
  - Effect of rotation of the Earth on wind direction
- Relative humidity and precipitation

</td><td>

- Experiments to illustrate the expansion of a fixed parcel of air on heating
- Experiment to investigate the pressure and volume relationship of a fixed parcel of air
- Compare the heating and cooling rates of land and sea
- Measure the maximum and minimum temperatures during a day
- Experiments to demonstrate the effects of atmospheric pressure
- Illustrate the vertical variation of pressure with height using a water tank with holes at different heights
- Activity to demonstrate the Coriolis effect on wind direction
- Design an experiment to show dew formation
- Join the activities organised by the Hong Kong Meteorological Society

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1.3 Hong Kong's weather patterns and weather forecasting • Weather patterns – Seasonal pattern and diurnal pattern: monsoon and land-sea breeze – Summer: cyclone and trough – Winter: anticyclone and ridge • Weather forecasting – Collecting data: wind speed and direction, temperature, pressure and humidity – Generating weather maps for making weather predictions	• Identify the prevailing wind pattern in summer and winter from weather maps of Hong Kong • Track the path of tropical cyclones from archived data • Draw flow diagrams to show the mechanisms of a monsoon and land-sea breeze • Use different instruments for measuring temperature, atmospheric pressure, humidity and wind speed • Information search on methods of collecting weather data (e.g. using weather balloon, satellite and radar as remote sensing tools) • Interpret satellite and radar pictures • Identification of simple weather systems on a weather map (e.g. cyclone, troughs and ridges) • Discuss the limitations of Numerical Weather Prediction (NWP) as an automatic system for weather forecasting • Visit the website of the World Meteorological Organisation and discuss its role in international weather monitoring
1.4 Air pollution in Hong Kong • Air Pollution Index (API) – Criteria air pollutants: carbon monoxide, sulphur dioxide, nitrogen dioxide, ozone, respirable suspended particulates (RSP) – Some non-criteria pollutants: volatile organic compounds, dioxins – Health implications of API • Sources and formation of some common air pollutants (e.g. sulphur dioxide, nitrogen oxides, ozone, particulate matter (PM_{10} and $PM_{2.5}$), volatile organic compounds) and their effects	• Visit the website of the Environmental Protection Department for information on API and relevant environmental ordinances • Identify the major contributing pollutants in different areas of Hong Kong using the API data • Plot graphs of variations in concentration of different air pollutants using data from the Environmental Protection Department • Identify any trends in API (daily and seasonal) from graphs of API data • Internet search on the disastrous London smog in 1952

<table>
<tr><td colspan="2">1.5 Transportation and stagnation of air pollutants</td></tr>
<tr><td>
• Weather phenomena that have an effect on air quality
– Monsoon
– Land-sea breeze
– Typhoon
– Rainfall
• Topography and urbanisation in the trapping of air pollutants
</td><td>
• Identify any correlation between weather and the air quality in Hong Kong by analysing archived data at the Hong Kong Observatory and Environmental Protection Department
• Watch animation on the transportation and dispersion of air pollutants in different seasons and different topographic environments
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<tr><td colspan="2">1.6 Energy use and air quality</td></tr>
<tr><td>
• Relationship between a fossil fuel based economy and air quality in Hong Kong
• Role of individuals, industry and government in helping to improve air quality
– Energy saving and energy efficiency
– Clean production of energy at source (e.g. cleaner fuel and technology) and control of emission
– Use of Environmental Impact Assessment (EIA) in town planning and regional zoning
</td><td>
• Compare the energy efficiency of a ordinary light bulb and a compact fluorescent lamp
• Information search on the Energy Efficiency Labelling Scheme and the Hong Kong Energy Efficiency Awards
• Discuss measures to reduce urban heat island effect in town planning
• Write an action plan or design a poster on practices that can help clean the air
• Information search on technological advances in car engines that have contributed to the reduction of pollutants
• Study the product brochures of different indoor air cleaning devices and find out the principles behind these devices
• Role play on a town planning board meeting on setting up a new town in Hong Kong, considering the influence of topography and seasonal weather patterns on the dispersion of air pollutants
• Search UNFCCC website to look for information of the Kyoto Protocol
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Module highlights
In this module, students have opportunities to:
• recognise that scientists investigate, describe and explain weather phenomena in terms of systems (e.g. the atmosphere, a cyclone)
• appreciate how scientists attribute weather phenomena to the interactions between parameters (e.g. temperature, pressure, relative humidity) and make weather forecast through mathematical modelling based on known relationships between these parameters
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- recognise that atmospheric systems of different scales may interact with and influence each other, resulting in a variety of weather phenomena (e.g. the movement of cyclones in response to other weather sub-systems)
- appreciate the usefulness of modelling in predicting the behaviour of a system (e.g. the use of NWP in weather forecasting)
- recognise that the reliability of modelling in weather forecasting is limited by the accuracy of the data and the design of the model and hence is subject to modification or rejection with scientific advances
- appreciate that the air pollution index is a product of scientists' efforts to describe and monitor air quality in a quantitative way
- appreciate that scientists may disagree on explanations or predictions made by peers based on shared data and that they critically review conflicting claims about science issues (e.g. they may attribute different causes to local air pollution)
- develop a concern for the air quality of Hong Kong and a commitment to practices that help to control air pollution through energy conservation and efficient use of energy
- develop a willingness to participate in public discourse about clean alternatives to fossil fuel power at the local and international levels
- review critically the relationship between the air quality in Hong Kong, weather patterns and the fossil fuel based economy

E 2 Keeping Ourselves Healthy

Overview

Introduction

Health and disease are two opposite sides of the same unity. Maintaining good health reduces the risk of disease. Apart from genetic composition, life style (such as balanced diet, regular exercise and stress management) and precautionary measures (such as separation from infectious pathogens and vaccination) are the most important factors affecting health.

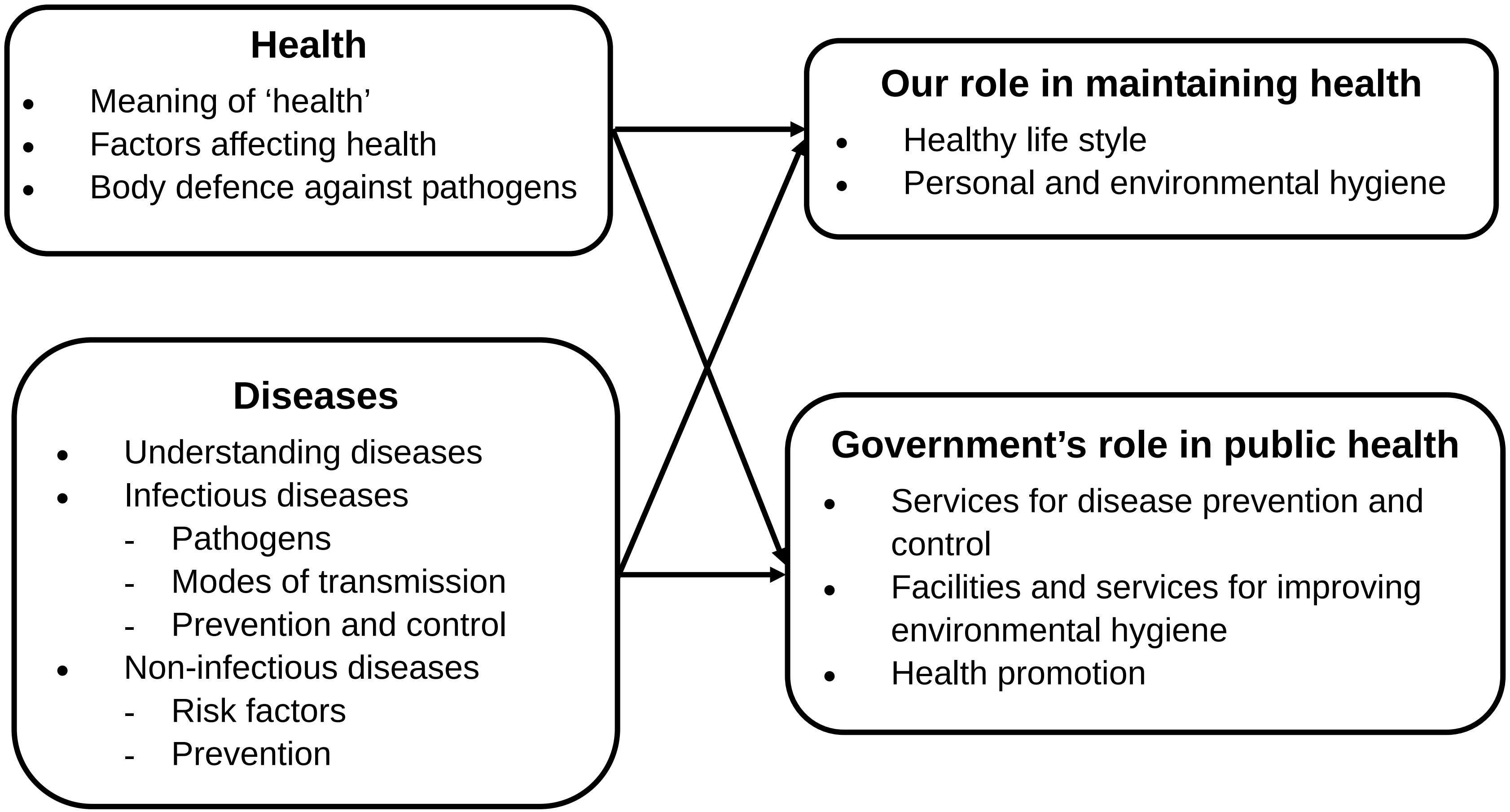
Knowledge about diseases is the key to their prevention. Infectious diseases pose an immediate threat to the health of the public at large. An understanding of the cause and mode of transmission of an infectious disease is essential to its prevention and control. The fight against SARS illustrates how scientists working with different approaches can contribute to the understanding of a new disease. The basic principle of defence mechanisms in the body is included in this module. Treatment and control measures for infectious diseases are also briefly described.

The number of cases of non-infectious diseases such as cancers and cardiovascular diseases is increasing rapidly in many parts of the world. Epidemiological studies have made a very significant contribution to the identification of the risk factors associated with these non-infectious diseases. Such knowledge enables us to take action to prevent the development of these diseases. A growing understanding of these and some other non-infectious diseases (e.g. genetic diseases) has driven the government to provide services (e.g. neonatal screening for G6PD deficiency) and implement policies (e.g. anti-smoking measures) that help to maintain public health. Students are led to recognise their roles and the role of the government in disease prevention and control.

Focusing Questions

- What is meant by 'health'? What factors affect health?
- How do scientists understand diseases?
- What are the main fatal non-infectious diseases in Hong Kong? What are the risk factors for these diseases?
- What are infectious diseases? How can we prevent and control these diseases?
- How does our body defence system protect us from the invasion of pathogens? How does our body fight against pathogens?
- What responsibilities do individuals and the government have with regard to disease prevention and control?

Module Organisation



E 2: Keeping Ourselves Healthy

Students should learn	Suggested learning and teaching activities

2.1 Health
• The meaning of 'health'
• Factors affecting health
  – Diet and eating habits
  – Rest and exercise
  – Stress
  – Other life styles (e.g. smoking, drinking)
	• Examine the validity of the claims of some health food supplements
	• Discuss health problems (e.g. stomach ache, obesity and hypertension) associated with poor eating habits, based on scientific principles

2.2 Diseases
• Types of diseases
  – Infectious and non-infectious
• The different approaches to understanding diseases
  – The clinical approach: focusing on the symptoms of and treatment for the disease
  – The pathological approach: focusing on the causes of the disease
  – The epidemiological approach: focusing on the factors determining the frequency and distribution of the disease in a population
	• Study the collaborative work of Barry Marshall and Robin Warren (Nobel prize winner, 2005) to appreciate how instruments, and the interaction of theorising and experimentation contributed to the discovery of the bacterial cause of peptic ulcers
	• Read about how John Snow investigated the London Cholera epidemic in 1854 with his statistical mapping methods to appreciate the importance of epidemiological study to public health
	• Review the outbreak of SARS in 2003 to appreciate how experts in different fields employing different approaches collaborated to help understand the cause, transmission mode and control of this new disease

2.3 Infectious diseases
• Evidence leading to the germ theory of diseases
• Types of pathogens
• Examples of infectious diseases and their modes of transmission
  – Water or food borne (e.g. cholera)
  – Air borne (e.g. influenza)
  – Blood borne (e.g. hepatitis B and AIDS)
  – Vector borne (e.g. dengue fever)
  – Direct contact (e.g. athlete's foot)
	• Read about the development of the germ theory of diseases and its implications for disease control and treatment
	• Use photomicrographs/ electronmicrographs to identify some pathogens (e.g. viruses, bacteria, fungi)
	• Information search on the various influenza pandemics in the 20th century
	• Discuss the possibility of the transmission of Avian influenza viruses between birds and from birds to humans

• The scientific principles of the prevention and control of infectious diseases • Use of antibiotics and the consequences of their indiscriminate use	• Design and perform an investigation to compare the effects of different disinfectants on the growth of microbes • Read about the discovery of antibiotics, and identify factors (e.g. the emergence of new evidence, hard work, luck) which affected the contribution of different scientists to this discovery • Use computer modelling to demonstrate how the indiscriminate use of antibiotics leads to drug-resistance • Survey to find out the use and misuse of antibiotics in Hong Kong • Information search on the problem of MRSA (methicillin resistant *Staphylococcus aureus*) or MDR TB (multi-drug resistant tuberculosis)
2.4 Non-Infectious diseases	
• Roles of epidemiological studies in understanding non-infectious diseases – Describing the diseases at the population level – Identifying possible risk factors – Suggesting causation between risk factors and the diseases – Evaluating prevention strategies • Cancer: possible risk factors and treatment for major types in Hong Kong (e.g. lung cancer, liver cancer, colorectal cancer and breast cancer) • Cardiovascular diseases: diet and life style which help to prevent coronary heart disease, strokes and hypertension • Genetic diseases – Prenatal screening (e.g. Down syndrome) – Neonatal screening (e.g. G6PD deficiency) for genetic diseases – Genetic counselling (e.g. thalassemia) • Degenerative diseases: diet and life style which help to prevent osteoporosis	• Conduct an epidemiological study of a hypothetical disease: identifying the suspected causes based on epidemiological clues, formulating hypotheses and carrying out investigations to test the hypotheses • A review of the epidemiological evidence that supports the causal relationship between smoking and lung cancer • Compare the incidence of various types of cancer in Hong Kong and globally • Information search on various cancer screening techniques, e.g. smear tests and breast imaging to appreciate how technology helps in diagnosing the disease • Compare the trends in the incidence of various types of cardiovascular diseases for both sexes and among different age groups in Hong Kong • Propose strategies to carry out a campaign for different age groups to raise awareness of their responsibilities in preventing cancer and cardiovascular diseases.

2.5 Body defence against pathogens	
• Non-specific immune response – The physical and chemical barriers for preventing the entry of pathogens (e.g. skin, blood clotting, acid in stomach, mucus and cilia in the respiratory tract) – White blood cells for engulfing pathogens in the body • Specific immune response – An outline of immune responses mediated by B cells and T cells – Primary immune response and secondary immune response • Vaccination	• Examine the features of mammalian skin that are related to body defence using prepared slides or models • Use audio-visual materials to demonstrate the production of antibody in response to an antigen, and the antigen-antibody reaction • Use audio-visual materials to demonstrate how vaccination works • Read about the scientists involved in the development of vaccination
2.6 Government's role in public health	
• Services for disease prevention and control – Immunisation programme, genetic counselling • Facilities and services for improving environmental hygiene – Water treatment, sewage treatment • Health promotion – Promotion of practices enhancing personal hygiene and healthy life styles	• Read about Yersin's discovery of the bacteria causing the Black Death Plague in Hong Kong in 1894 • Discuss the advantages and risks of vaccination to both individuals and the community • Information search on the reasons for organising cervical screening programme in Hong Kong

Module highlights

In this module, students have opportunities to:

- develop a commitment to adopt diets and life styles that are conducive to physical and mental health
- develop an attitude of informed scepticism about the use of health products and treatments that claim to promote health
- appreciate that the different approaches adopted in the study of diseases are scientific inquiries focusing on different aspects of a disease
- realise that the establishment of the cause of a specific infectious disease requires collaborative effort among scientists in different fields (e.g. microbiology, pathology, histology and clinical research)
- appreciate that the epidemiological study of diseases involves the collection of data, making logical deductions from the data to form a hypothesis, and testing the hypothesis in a carefully designed investigation
- realise that sporadic changes in the structure of viruses are unpredictable and make the production of vaccines against them difficult

- appreciate that the immune system is one of the sub-systems of the body system which plays an important role in safe-guarding our health
- appreciate how the structure of the skin allows it to act as a physical barrier to pathogens (form and function)
- realise that the misuse of antibiotics enhances the evolution of drug-resistant bacteria
- develop a commitment to keep good personal hygiene to help prevent disease transmission
- appreciate the efforts of the government in improving sanitation (e.g. water purification, construction of sewers and sewage treatment plants, containment and disposal of garbage) to reduce disease transmission
- appreciate the government's provision of free immunisation programme in Hong Kong for preventing diseases
- realise that prenatal screening can raise ethical dilemmas

E 3 Chemistry for World Needs

Overview

Introduction

Since the dawn of time, natural curiosity about the materials in the world has driven people to experiment with different substances. They may break a substance down to examine its parts, reunite its parts in different ways or combine different substances together to make a new substance. All these not only contribute to our understanding of the nature and properties of the materials around us, but also provide a platform for scientists to obtain useful substances from natural resources and synthesise chemicals and materials to improve our lives.

In this module, students are introduced to four types of chemicals that have changed the world. Fertiliser, detergent, chlorine bleach and polymer have been prepared by scientists in the laboratory and are now being produced in an industrial scale. An understanding of the dynamic nature of chemical equilibrium and factors that affect the rate of a reaction have enabled the mass production of these chemicals and materials.

The production of detergent, chlorine and chlorine bleach has helped to safe-guard our health. The mass production of fertiliser has largely increased crop yield to help feed the escalating growth of our population. The vast increase in the number and types of synthetic polymers in the last 50 years has revolutionised our modern living. Putting materials to practical uses is very often need-driven, whereas the development of materials is sometimes a serendipitous discovery. These stories of discovery are intriguing, and students will come to see how an understanding of the microstructure-property relationship in polymers and polymerisation process allows scientists to design and synthesise new materials for our everyday use.

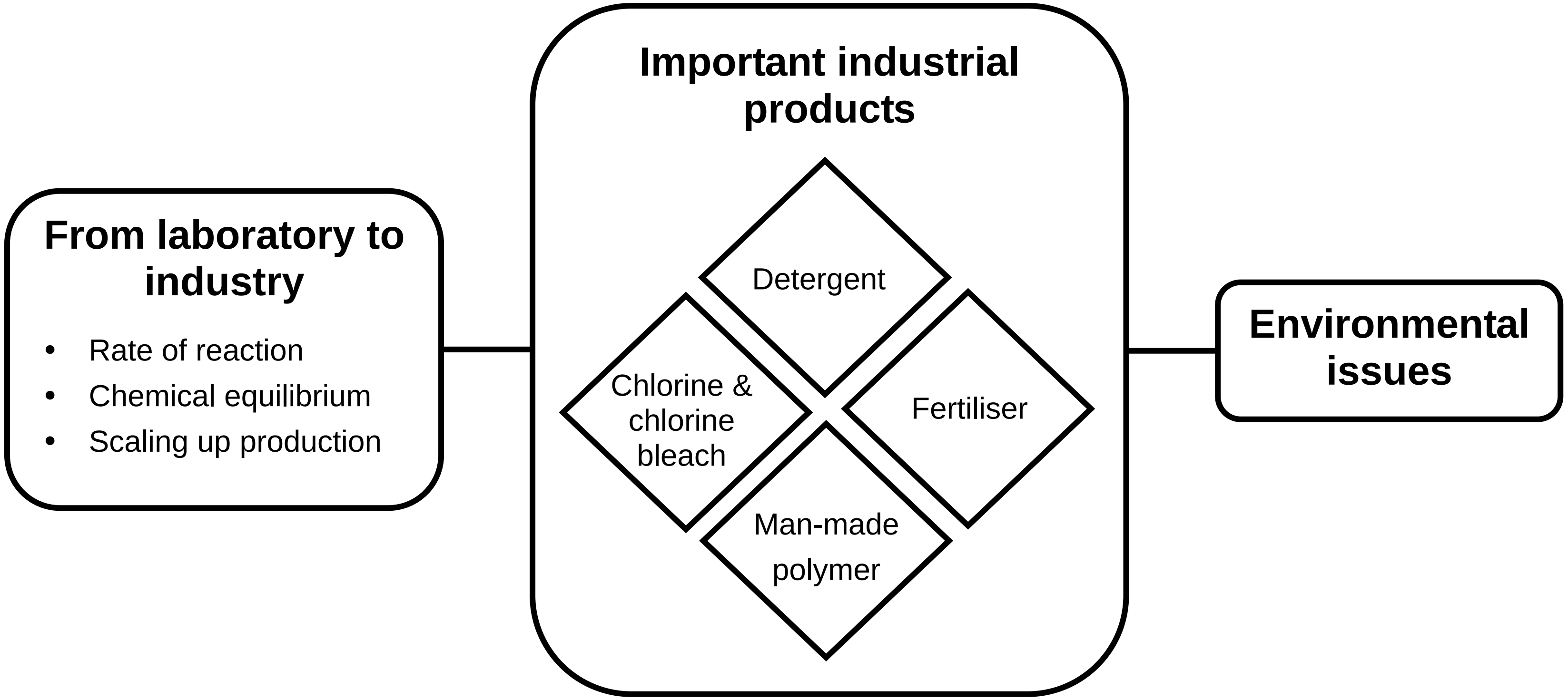
The popular use of fertiliser, detergent, chlorine bleach and plastics is not without cost. The environmental problems associated with the use of these substances have raised considerable concern. Finding the solutions and making the best decisions with limited resources provide a great challenge to scientists.

Focusing Questions

- How are rates of reaction controlled?
- How can chemical reactions in the laboratory be scaled up to industrial production?
- How do scientists convert nitrogen in the air and sodium chloride in seawater to produce chemicals for making fertiliser and disinfectants?
- How are plastics with different properties made?

- In what ways are plastics used in daily life?
- What are the environmental problems associated with high consumption of detergent, chlorine bleach, fertiliser and plastics? How can scientists and ordinary citizens help in providing solutions to these problems?

Module Organisation



E 3: Chemistry for World Needs

Students should learn	Suggested learning and teaching activities
3.1 From Laboratory to Industry • Factors affecting the rate of a reaction • Reversible reactions, chemical equilibrium and product yield • Factors to consider in scaling up production – Availability of raw materials – Market value of the product – Efficient use of energy – Environmental concerns	• Experiment to study the conservation of mass in a simple chemical reaction • Measure the rate of a reaction by following the rate of disappearance of a reactant or the rate of appearance of a product • Design and perform experiments to study the effects of concentration, surface area, temperature and the presence of catalysts on the rate of reaction • Investigate some reversible reactions (e.g. varying the acidity of potassium dichromate solution, and of bromine water) • Discuss the roles of chemical researchers, marketing officers, chemical engineers and administrators in a chemical plant
3.2 Chemicals for personal, household and public hygiene	
• Detergent – Detergent as a substance which helps to remove dirt by: its ability to act as a wetting agent, and its emulsifying action – Structures of soap and soapless detergents – Emulsifying properties of detergent in relation to its structure – Environmental problems associated with the use of detergent • Chlorine and chlorine bleach – Importance of chlorination in water treatment and the use of chlorine bleach in public hygiene – Production of chlorine by electrolysis of brine – Manufacture of chlorine bleach from chlorine – Appropriate and safe use of chlorine	• Investigate the properties of detergent as a wetting agent and an emulsifying agent • Prepare soap from cooking oil and compare its cleaning properties with that of commercial detergents • Search for information on the environmental problems associated with the use of detergent and the efforts scientists have made to solve the problems • Discuss the use of chlorine bleach at home and in public places • Prepare a 'chlorine bleach' by the electrolysis of brine and allowing the chlorine gas produced to react with the resulting solution • Compare the production of chlorine bleach in the laboratory and in industry • Examine the labels on household

– bleach for household cleaning – Limitations of the use of chlorine and chlorine bleach for disinfection	chlorine bleaching products and identify the relevant safety precautions in using them • Compare the use of chlorine and chlorine bleach with that of hydrogen peroxide and ozone as disinfectants
3.3 Chemicals for agriculture • Solving the nitrogen problem for enhancing plant growth – Sources of nitrogen for healthy plant growth – Natural fertiliser and synthetic fertiliser – The Haber Process and its contribution to agriculture – Environmental problems caused by leaching • Solving the pest problem – Development of pesticides to protect crops – Pros and cons of using pesticides – Qualities of an ideal pesticide	• Information search on the essential elements required for healthy plant growth • Make fertiliser in the laboratory (e.g. ammonium sulphate from aqueous ammonia) • Design and perform experiments to investigate the effects of fertiliser on the growth of green bean seedlings • Draw flow diagrams to illustrate the manufacture of ammonia using the Haber Process • Case study on the rise and fall of DDT as a pesticide • Information search on the recent development in the use of pesticides • Discuss the properties of an ideal pesticide
3.4 Man-made polymers fit for different purposes	
• Polymers as large molecules made up of the same repeating unit • Synthesising polymers for desired properties – Obtaining building blocks: by-products from petroleum refining process – Making polymers: polymerisation, vulcanisation – Properties: thermal, mechanical and their relationships to microstructure – Modifying the properties of polymers for various purposes: garment, packaging, parts for making tools • Environmental issues related to the use of plastics • Responsible use of plastics: reduce,	• Read about how Fawcett and Gibson invented polythene • Prepare some GLUEP from water, borax and glue • Use ball-and-stick models to illustrate the process of polymerisation • Make models to show the structures of cross-linked polymers, reinforced polymers and plasticised polymers • Prepare nylon fibres • Carry out a fair test to compare the strength and thermal insulating properties of different plastics • Information search on the codes on plastic articles used for recycling purposes • Discuss the limitations of the recycling of plastics

reuse, recycle, replace and remediate • Development of degradable plastics	• Perform Life Cycle Assessment of paper bags and plastic bags • Information search on smart materials and their applications

Module highlights

In this module, students have opportunities to:

- recognise that a chemical reaction takes place in a system in which the reactants interact to give the products under certain conditions
- realise the importance of catalysts in chemical reactions in our body (e.g. enzymes in metabolic reactions) and in chemical synthesis (e.g. iron in the Haber Process)
- realise that, in a chemical reaction, the atoms of the reactants are not destroyed but are reshuffled to give the products (conservation of matter)
- recognise that the molecular structure of detergent enables it to become an emulsifying agent in cleaning processes (form and function)
- appreciate that the form in which an element exists determines its function (e.g. most plants can utilise nitrogen in nitrates in making amino acids but not nitrogen in molecular form; and chlorine gas is a disinfectant, while chloride is not)
- appreciate how scientists manipulate the reaction conditions to optimise the synthesis of products using their understanding of dynamic equilibrium
- realise that the serendipitous discoveries of useful chemicals (e.g. celluloid, Teflon) are often a result of scientists' creativity and the use of logic
- realise that advancements in science, as illustrated by the development of different plastics, are often driven by the need to solve problems
- appreciate that scientists use molecular models to explain the properties of plastics and design better materials
- appreciate how scientists and chemical engineers apply chemical principles and scientific methods to solve authentic problems in industry
- appreciate that the production of chemical products, while satisfying the needs of consumers, may create environmental problems
- realise that the synthesis of useful chemicals and development of new plastics are influenced by technological advances, consumer needs and economic factors
- develop a sense of responsibility to maximise the usefulness of plastic products and contribute to the sustainable development of our society

2.4 Learning Outcomes

By the end of the course, students are expected to have developed scientific literacy and be capable of demonstrating the following competencies:

2.4.1 Knowledge and Understanding

Students should be able to

- show an understanding of a range of phenomena, facts, principles, concepts, laws and theories, and key ideas in science;
- apply a range of practical techniques and process skills, terminologies and conventions specific to the study of science in solving problems;
- recognise the explanatory frameworks of science and the ways in which reliable knowledge of the natural world is obtained;
- identify the unifying concepts in science and use them as conceptual tools for thinking and making sense of the world; and
- apply scientific knowledge, concepts and principles to explain phenomena and observations, and to solve problems in everyday life.

2.4.2 Skills and Processes

2.4.2.1 Scientific Thinking

Students should be able to

- critically examine scientific evidence;
- recognise how the interpretation of data, using creative thought, provides evidence to test ideas and develop theories;
- recognise the importance of evidence in supporting, modifying and refuting proposed scientific theories;
- use data in developing arguments for or against claims of cause-effect links;
- formulate generalisations in the light of both first- and second-hand evidence;
- recognise that the application of inductive and deductive logic leads to the emergence of new scientific theories, which are then tested empirically;
- recognise how explanations of many phenomena can be developed using scientific theories, models and ideas;
- recognise the fundamental role of models in exploring observed natural phenomena and that models are modified as new or conflicting evidence is found;
- recognise that two (or more) scientists may legitimately draw different conclusions

about the same data;

- recognise that there are some questions that science cannot currently answer, and some that it cannot address; and
- apply the concept of a system in analysing changes and equilibrium, and solving problems.

2.4.2.2 Scientific Investigation

Students should be able to

- identify problems from observations and formulate hypotheses for investigation;
- design and conduct experiments for testing the hypotheses set;
- select appropriate methods and apparatus to carry out investigations;
- record observations, interpret experimental data, and interpolate and extrapolate from data collected;
- look for patterns in data, as a means of identifying possible cause-effect links and working towards explanation;
- use graphical techniques appropriately to display experimental results and to convey concepts of science;
- draw conclusions from the findings of investigations;
- evaluate the validity and the reliability of experimental results and identify the factors affecting their validity and reliability; and
- evaluate the conclusions, and plan for further investigations if appropriate.

2.4.2.3 Practical Skills

Students should be able to

- follow procedures to carry out experiments and field work safely;
- handle chemicals and apparatus safely and properly;
- recognise the need for accurate measurements, select appropriate instruments and realise the limitations of the instruments used;
- build models to aid comprehension; and
- evaluate experimental methods and suggest possible improvements.

2.4.2.4 Problem-solving

Students should be able to

- clarify and analyse problems related to science;

- apply knowledge and principles of science to solve problems;
- think critically, and suggest creative ideas and solutions to problems;
- propose solution plans and evaluate their feasibility;
- devise appropriate strategies to deal with issues that may arise; and
- tolerate the uncertainties and ambiguities faced during the course of resolving difficulties.

2.4.2.5 Information handling

Students should be able to

- search, retrieve, reorganise, analyse and interpret scientific information from a variety of sources;
- use information technology to manage and present information;
- evaluate the accuracy and credibility of information from secondary sources; and
- distinguish among fact, opinion and value judgment in processing scientific information.

2.4.2.6 Informed Decision-making

Students should be able to

- collect evidence, and judge the validity and reliability of the data in making decisions on issues related to science;
- discuss and critically evaluate scientific issues that have social, economic, environmental and ethical implications;
- make decisions based on the examination of evidence and arguments;
- recognise that assessing and comparing the risks of an activity, and relating these to the benefits we gain from it, are important in decision making; and
- support judgments using appropriate scientific principles.

2.4.2.7 Independent Learning

Students should be able to

- develop study skills to improve the effectiveness and efficiency of their learning;
- engage in simple self-learning activities in the study of science – collecting evidence or finding and analysing scientific information; and
- develop learning habits, abilities and attitudes that are essential to lifelong learning.

2.4.2.8 Communication Skills

Students should be able to

- use symbols, formulae, equations and conventions appropriately;
- interpret scientific information from text and data presented in verbal, diagrammatic, numerical, tabular and graphical forms;
- organise, present and communicate ideas and arguments in a clear and logical manner;
- communicate scientific ideas in a meaningful and creative way;
- read and understand articles involving contemporary issues in science; and
- use information technology to process and present scientific information.

2.4.2.9 Collaboration

Students should be able to

- participate actively, share ideas and offer suggestions in group discussions;
- liaise, negotiate and compromise with others in group work;
- identify collective goals, and define and agree on the roles and responsibilities of members in science projects requiring team work;
- act responsibly to accomplish allocated tasks;
- be open and responsive to ideas and constructive criticisms from team members; and
- build on the different strengths of members to maximise the potential of the team.

2.4.3 Positive Values and Attitudes

Students should

- develop curiosity and interest in science;
- develop personal integrity through objective observation and honest recording of experimental data;
- develop a habit of self-reflection and the ability to think critically;
- demonstrate perseverance and continued interest in the pursuit of scientific knowledge;
- recognise the importance of the safety of oneself and others in the laboratory and be committed to safe practices in daily life;
- develop open-mindedness and be able to show tolerance and respect towards the

opinions, decisions and value systems of others even in disagreement;

- develop informed and healthy scepticism based on recognition of limitations of science;
- accept the provisional status of the knowledge and theory of science and develop a willingness to tolerate uncertainty;
- appreciate the wonders of Nature and show respect and care for all forms of life;
- recognise the imminent need for conservation and act responsibly in conserving the environment;
- develop a positive attitude in enhancing personal and community health;
- recognise the social, ethical, economic, environmental and technological implications of science and develop an attitude of responsible citizenship; and
- be willing to contribute to the betterment of mankind in local, national and global perspectives based on the acquired scientific knowledge.

Chapter 3 Curriculum Planning

This chapter provides guidelines to help schools and teachers to develop a flexible and balanced curriculum that suits the needs, interests and abilities of their students, and the contexts of their schools, in accordance with the central framework provided in Chapter 2.

3.1 Guiding Principles

The ultimate purpose of curriculum planning is to improve student learning. The Integrated Science curriculum is structured in thematic modules, which allows for flexibility and innovation in curriculum planning. Each school is encouraged to adapt the Integrated Science curriculum by varying the organisation of content, learning and teaching strategies, and the criteria and modes of assessment, to ensure that their students achieve the learning targets. Noted below are some major principles for curriculum planning that teachers should bear in mind when adapting the curriculum:

- Build on the knowledge students gained in basic education
- Organise the curriculum to encompass its various targets
- Make students' learning more purposeful through linkage with their learning experiences in other KLAs
- Promote independent learning and foster the capacity to 'learn how to learn'
- Contribute to a balanced and coherent learning experience for students through fostering their generic skills
- Make flexible use of class time to facilitate learning

3.2 Progression

3.2.1 Students' Prior Knowledge

In planning and developing their own school-based curricula, teachers should note that the Integrated Science curriculum is built on the core part of the Science (S1-3) curriculum, with which it shares common features, such as the emphasis on scientific investigation and the cultivation of scientific literacy. Schools should ensure effective progression from junior to senior secondary levels by completing the core part of the Science (S1-3) curriculum before starting the Integrated Science curriculum in S4. Appendix 2 shows how the various modules in the Integrated Science curriculum are related to students' prior knowledge developed in the Science (S1-3) curriculum. Apart from knowledge and understanding, students are expected to have a solid foundation in the following areas related to scientific thinking and investigation:

- Focusing and planning (e.g. asking testable questions, proposing hypotheses, controlling variables and predicting results)
- Conducting experiments (e.g. observing, measuring, handling equipment)
- Analysing data (e.g. classifying evidence, interpreting data and communicating results)
- Reflecting on experimental results (e.g. inferring from data, evaluating methods and suggesting improvement)
- Using evidence to support and justify their arguments (e.g. the validity of claims, the effectiveness and limitations of scientific models, and decisions on environmental issues)

3.2.2 Sequencing

Since an interdisciplinary thematic approach is adopted in the design of the curriculum and concepts are not necessarily built up linearly for each discipline, it is important that teachers consider the progression and interaction of ideas in the various modules. A sequence for the eight modules in the Compulsory Part of the curriculum is suggested below. Though the modules do not follow on from each other exactly, the later modules require the ideas developed in earlier ones. If teachers choose to organise the modules in a different sequence, they should ensure that ideas and skills are built on progressively and that student learning becomes more complex as they construct new ideas and develop new skills.

Compulsory Modules

C1 Water for Living
C2 Balance within Our Body
C3 Science in a Sprint
C4 Chemical Patterns
C5 Electrical Enlightenment
C6 Balance in Nature
C7 Radiation and Us
C8 From Genes to Life

Within a particular module, teachers can organise the content in different sequences. For some of the modules (e.g. C1, C2, C8), we have included multiple teaching sequences for teachers' reference. Teachers can opt to use one of them or any other sequence they deem appropriate. A diagrammatic representation of the module organisation showing the interconnectedness between the concepts in the modules is also included. Our intention is to help teachers to think of learning and teaching in a more 'map-like' way, and to bring out the explicit connections between concepts where appropriate. Teachers need to help students to bring together the concepts they learn in a meaningful way; otherwise, the fragmented ideas they have acquired will be quickly forgotten.

3.3 Curriculum Planning Strategies

In planning for a school-based Integrated Science curriculum, it is important to achieve a balance across its different purposes, which include: the different facets of the curriculum targets; the development of skills in scientific investigations; and the generic skills advocated in the current curriculum reform. Schools are encouraged to consider the following curriculum planning strategies:

3.3.1 Organising the Different Facets of the Curriculum

In the Integrated Science curriculum, we emphasise the understanding of the main scientific explanations that give us a framework for making sense of the world and the broad patterns that cut across science disciplines. It is expected that after completing this curriculum, students will develop an understanding of (i) the key ideas in science, (ii) the nature of science and (iii) the unifying concepts that pervade science.

It is likely that all three of the above aspects will not be met to the same extent in each module. In planning a school-based curriculum, it is advisable to match the different modules to particular emphases, so that the different emphases can be covered more systematically and extensively. Theoretically, every module can be written to emphasise certain curriculum goals, but in each module there is usually one or more curriculum emphases that fit most naturally. For example, the module on 'Chemical Patterns' readily allows for the integration of ideas about the nature of science, whereas the module on 'Energy, Weather and Air Quality' naturally brings out ideas about the various unifying concepts. The 'Module highlights' in the table of content of each module has listed the opportunities offered in each module for the development of unifying concepts and nature of science and should be referred to in the planning of the school-based Integrated Science curriculum.

3.3.2 Fostering Autonomy in Scientific Investigation

The Integrated Science curriculum treats science as a way of thinking rather than a body of knowledge. It emphasises the cultivation in students of a way of thinking that is typical of scientists. This includes the ability to combine observation, experimentation, imagination and deliberation creatively and flexibly in pursuing solutions to personally relevant problems. Students should be provided with opportunities to design and conduct scientific investigations into problems of their own. They need to shape the questions themselves so that the investigations become their tasks. The more control that students exercise on what they do to learn, the greater the sense of ownership and, therefore, the greater the likely motivational power of the activity. So, in planning investigation activities, teachers should try to ensure that:

- The investigation is perceived by students to be challenging, meaningful and authentic (relevant to life outside the classroom).
- Students are given choices and are allowed to follow their own preferences.
- Timely feedback is provided on current levels of performance and advice is given for improvement in the future.

Listed below are some examples of areas which students might find it interesting to investigate:

- The design of sports shoes for different kinds of sports (C3)
- The causes and impact of algal bloom in Hong Kong waters (C6)
- Constructing and testing new polymers for a particular use by varying the amount of cross-linking agent (E3)

3.3.3 Nurturing Students' Generic Skills

In line with the current curriculum reform, the Integrated Science curriculum is designed for the development of generic skills. Some examples are listed below for teachers' reference:

Generic skills	Examples of opportunities for promoting the acquisition of generic skills in different modules
Communication skills	• Using a wide range of scientific and technical vocabulary and conventions to communicate information (e.g. the use of chemical symbols in writing chemical equations – C4) • Understanding and appreciating the viewpoints of people with different interests; resolving conflicts to solve problems concerning STSE issues (e.g. discussion on improving the air quality of Hong Kong – E1; discussion on ethical issues arising from the application of DNA technology – C8)

Critical thinking skills	• Evaluating key ideas, opinions and arguments identified from reading materials and synthesising them to construct their own interpretations for making judgments (e.g. evaluating the claim 'Life begins in water' – C1) • Recognising the usefulness and limitation of scientific models and theories (e.g. conceptualising electric current as flow of water – C5) • Interpolating or extrapolating to predict trends and patterns from a limited range of evidence and justifying their validity (e.g. discussion of the risks related to the use of low- and high-frequency radiations – C7)
Creativity	• Developing curiosity and interest in science (e.g. the observation of early scientists in the series of experiments on electricity and magnetism – C5) • Proposing solutions for science problems and evaluating their appropriateness (e.g. discussion of the use of radioactive materials in smoke detectors – C7) • Being willing to try new approaches or methods in solving problems (e.g. discussion on the methods for diminishing the harmful effects of chemical fertilisers and pesticides – E3)
Collaboration skills	• Agreeing on the roles and responsibilities of members in performing group experiments • Exchanging ideas and agreeing on realistic objectives for working together in a science project
Information technology skills	• Using animation and simulations to visualise scientific ideas (e.g. illustrating the processes of genetic information flow in a cell – C8) • Using IT tools to analyse and present information (e.g. the use of motion video analysis (MVA) in analysing motion – C3) • Using appropriate sensors and data-loggers to gather data from experiments which are too fast or too slow
Numeracy skills	• Making approximations and estimates to obtain reasonable answers • Reading, interpreting and drawing simple inferences from tables, statistical diagrams and graphs • Plotting graphs from data provided and selecting appropriate axes and scales

	• Recording information with consistent accuracy • Comparing the quality of information to be obtained from different graphs showing the same data • Developing simple models using algebraic and graphical methods (e.g. deriving equations from linear motion graphs – C3)
Problem-solving skills	• Recognising the complexity of a problem and searching for appropriate information to solve it • Proposing solution plans for scientific problems and evaluating their feasibility, validity and appropriateness (e.g. discussion of the various means for pollution control and waste treatment – C6)
Self-management skills	• Making informed decisions and safe choices in developing good habits and maintaining a healthy life style (e.g. in discussing health problems, such as stomach ache, obesity and hypertension, associated with poor eating habits, based on scientific principles – E2)
Study skills	• Extracting the main ideas and presenting them in an informative way (e.g. constructing concept maps to show the mechanism of blood glucose and temperature regulation – C2) • Planning and carrying out a self-study science project • Evaluating the effectiveness of a self-study plan

Figure 3.1 Opportunities for nurturing students' generic skills

3.3.4 Collaborating with other KLAs

It is important that students' learning is coherent and that learning experiences in their different curricula complement and supplement each other. There are many opportunities for cross-curricular learning for students depending on the other elective subjects they are taking. For example, the modules on 'Water for Living', 'Balance in Nature' and 'Energy, Weather and Air Quality' provide a good match with topics in Geography; and the module on 'Science in a Sprint' can be related to topics in Physical Education. Also, the modules on 'Balance within Our Body' and 'Keeping Ourselves Healthy' can be linked to the subject Health Management and Social Care; and students taking Business, Accounting and Financial Studies or Economics, will be able to discuss future investment opportunities in new technologies (e.g. the modules on 'From Genes to Life' and 'Chemistry for World Needs').

Last but not the least, the scientific explanations students acquire and the logical way of thinking they develop in this curriculum will support students' participation in discussions on the study area 'Science, Technology and the Environment' in Liberal Studies. To build a sound and robust school-based senior secondary curriculum, science teachers should collaborate with teachers of other KLAs, taking the following aspects into consideration:

- the students' needs, interests and abilities;
- the broad topics, themes and concepts that students will come across in the study of subjects in other KLAs; and
- the science concepts, investigation skills, thinking skills and study skills that are required for mastering subjects in other KLAs.

3.3.5 Flexible Use of Learning Time

As mentioned in Chapter 2, 270 hours (10% of the total curriculum time) should be allocated to cover this subject. Teachers are encouraged to use this time flexibly to help students attain all the different targets of the curriculum. Since students' interests are very diverse, they may find some of the modules more interesting and be more motivated to explore particular topics or issues in depth. The 14 hours allocated to scientific investigations can be flexibly used to carry out investigations into these topics. Schools are also encouraged to include half-day or whole-day activity sessions (shared among different KLAs) in the school time-table, to allow continuous stretches of time for field trips, visits, or scientific investigations.

3.4 Managing the Curriculum

Since Integrated Science is a new subject in the senior secondary curriculum, the concerted effort of science teachers, the Science Education KLA coordinator and the school head as curriculum leaders in different areas is necessary for the smooth implementation of the subject. Their roles are discussed below.

3.4.1 Role of School Head

The School Head should play a leading role in planning, directing and supporting school-based curriculum development as a whole. Heads need to understand the central curriculum framework, the strengths of their teachers and the needs and interests of their students. School Heads are encouraged to work closely with their Deputy Heads or Academic Masters/Mistresses to carry out their roles as curriculum leaders, which in Science Education involve:

- understanding the direction of curriculum reform and the aims and purposes of the various science subjects, so that holistic school-based science curriculum development can be promoted;
- appointing a Science Education KLA Head to coordinate the planning of the science curricula, to ensure coherence and continuity between junior and senior secondary levels;
- avoiding early curriculum specialisation at junior secondary level (e.g. early streaming);
- catering for students' diverse needs and aspirations by offering a variety of subject combinations through flexible timetabling;
- drawing up plans to cater for students with a strong interest and talent in science by referring to the Three-tier Model set out by the EMB in developing a long-term policy for the gifted education curriculum;
- working closely with the Academic Masters and Career Masters to help students make a good choice of elective subjects;
- providing 'taster' programmes in S4 and the necessary bridging programmes when students alter their choice of subjects in S5 or S6.
- deploying school resources appropriately (e.g. laboratories, laboratory technicians and equipment) to promote effective learning and teaching of the different science subjects and combinations on offer;
- promoting and facilitating a collaborative and sharing culture among teachers by reserving time for collaborative lesson preparation or peer lesson observation in the school time-table;
- drawing up a professional development programme for all teaching staff, in particular for teachers of the Integrated Science curriculum who have to teach beyond their subject expertise;
- encouraging and facilitating professional exchange and sharing of good practices through school networking on a face to face and electronic basis in support of the implementation of the Integrated Science curriculum;
- encouraging and facilitating cross curricular learning opportunities (e.g. project learning, reading science articles in the language classroom) to enhance knowledge integration and reduce teachers' and students' workload.

3.4.2 Role of Science Education KLA Coordinator

Due to the interdisciplinary nature of the curriculum, the Science Education KLA Coordinator has a very special role in the implementation of the curriculum. The Coordinator should act as the 'bridge' between the school administrative personnel and science teachers to ensure proper deployment of resources and collaboration among KLA members (including science teachers and laboratory technicians) for the curriculum by:

- setting clear and well-defined curriculum, instructional and assessment policies in line with the guidelines set out in the ***Science Education KLA Curriculum Guide (Primary 1 – Secondary 3)*** **(2002)**, ***Senior Secondary Curriculum Guide*** **(2007)** and the relevant Curriculum and Assessment Guides;
- ensuring a smooth interface between the Key Stages by working closely with different science panels to ensure coherence and continuity in planning and implementing the various science curricula;
- having a good knowledge of the facilities and resources (e.g. laboratory facilities and equipment) available and allocating the resources between the different panels for the implementation of the Integrated Science curriculum;
- playing a leading role in building a positive and harmonious culture for sharing among KLA members by holding regular review meetings, peer coaching, peer lesson observation, collaborative lesson preparation, and a mentoring scheme;
- leading KLA members to design appropriate learning tasks and activities to help students work towards the aims and learning targets laid down in the relevant curriculum documents;
- enhancing the professional development of KLA members by encouraging and facilitating their participation in professional development courses, workshops, seminars and R&D projects;
- keeping abreast of the developments in science and supporting the learning and teaching of the Integrated Science curriculum by building up a resource corner for up-to-date science news, learning and teaching materials, and education magazines for teachers' professional growth;
- nurturing students' interest in science by organising thematic Science Day; interclass science project competitions, participating in interschool science activities, etc.;
- cooperating closely with KLA members to ensure safety by conducting risk assessments and taking precautionary measures in performing practical work and scientific investigations.

3.4.3 Role of Science Teachers

The interdisciplinary nature of the Integrated Science curriculum inevitably brings challenges to teachers both in terms of their subject expertise and their capacity to be resource persons, facilitators, and role models of scientifically literate citizens. It is therefore, essential that teachers of Integrated Science work closely together to bring the curriculum alive by:

- being acquainted with the aims of the Integrated Science curriculum and the learning focus of each module and sharing them explicitly with students;
- keeping abreast of new developments in science and encouraging their students to explore these developments;
- providing learning contexts that are relevant to students' daily lives, so that they realise the intertwining nature of science, technology, society and environment;
- developing meaningful and challenging activities to motivate students and develop their scientific thinking skills;
- engaging students in discussions about links between ideas, evidence and argumentation in scientific theory and experimentation;
- making use of the flexibility in the thematic modules to foster students' autonomy in learning by allowing them to shape their own scientific investigations;
- employing a variety of modes of assessment to assess students' learning and providing timely feedback to students on their current performance and how they can improve;
- participating actively in professional development courses, workshops, seminars, and school networks by sharing their teaching ideas and classroom practices to support the work of their peers.

For details of the role of teachers as key change agents, please refer to Chapter 9 of ***The New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong* (2005)**, and Booklet 8 of the ***Senior Secondary Curriculum Guide* (2007)**.

3.4.4 Flexible Staff Deployment

If Integrated Science is to be taken by a class of students as a single elective subject, the normal time-tabling for elective subjects can be adopted. It is common practice in schools for teachers to be involved in teaching a course for three years. However, due to the multi-disciplinary nature of this subject, schools may consider assigning teachers with different expertise to teach this subject at different levels (S4, 5 and 6), or two teachers of different subject expertise to teach one class, so that teachers can focus more on modules with which they are familiar. This also helps share out the effort required in preparing for the new curriculum.

We encourage schools to promote partnership in the preparation of lessons, team teaching and lesson observation, so that teachers can learn from each other. It is recommended that schools reserve time for collaborative lesson planning in the time-table so that teachers can work together.

In cases where a school is offering this subject to two or more classes, it is advisable to assign teachers with different subject expertise to the different classes. With special time-tabling, it will be possible to swap classes so that teachers can concentrate on the modules they know best. After a few years, the teachers will be able to cover the teaching of the whole curriculum and be better placed to monitor the progress of the students.

The following table illustrates the different arrangements that schools may adopt, according to their resources and the readiness of their teachers:

Option A:	One teacher teaches one class at all three levels. If the teacher is required to teach beyond his/her own expertise, more time should be allowed for his/her professional development in knowledge updating and lesson preparation.
Option B:	Teachers with different expertise share the teaching of one class. This allows them to concentrate on preparing the modules in the areas in which they are most knowledgeable.
Option C:	Two teachers with different expertise teach two classes, with each teaching one class. These teachers should share their knowledge and experience regularly and help each other in preparing resources.
Option D:	Two teachers with different expertise teach two classes, with a special time-tabling arrangement which allows them to swap their responsibilities at various times in the year.

Figure 3.2 Flexible staff deployment for the Integrated Science curriculum

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Chapter 4 Learning and Teaching

This chapter provides guidelines for effective learning and teaching of the Integrated Science curriculum. It is to be read in conjunction with Booklet 3 in the ***Senior Secondary Curriculum Guide*** **(2007)**, which provides the basis for the suggestions set out below.

4.1 Guiding Principles

Learning and teaching are interactive processes; they involve complex and dynamic relationships between the individual learner, the teacher, and the learning context. A good understanding of science, of the aims and the learning targets of the curriculum and of how students learn will lead to the effective organisation of learning experiences for students, which in term will lead to effective learning among students. The diagram below depicts this.

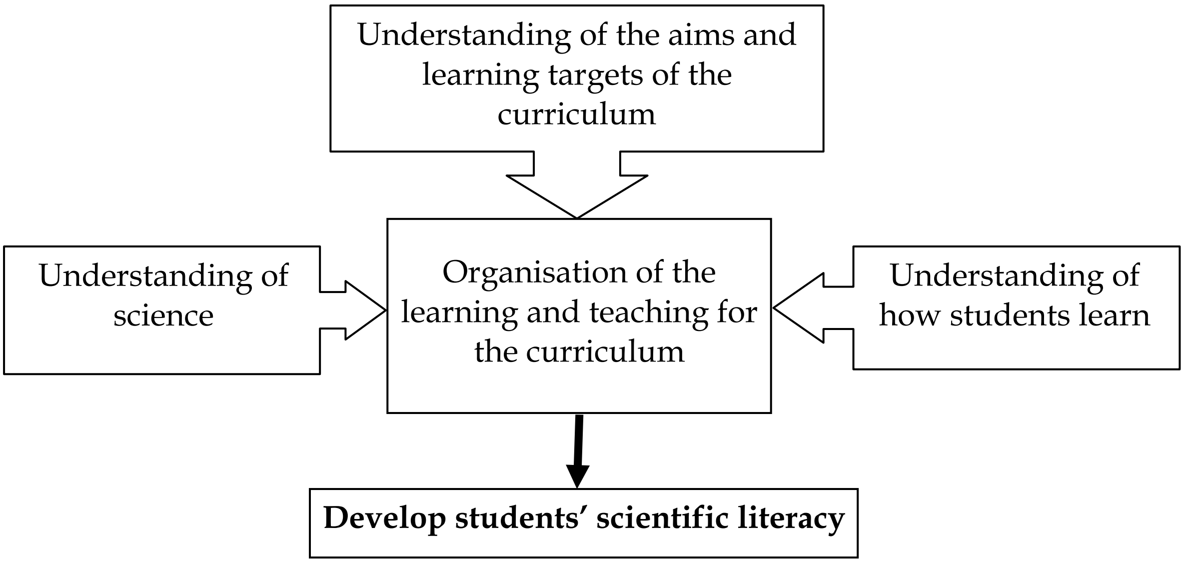

Figure 4.1 Organising the learning and teaching for the curriculum

The aim of this curriculum is to empower students to be inquisitive, reflective and critical thinkers through participation in a range of science learning experiences, so that they develop a level of **scientific literacy** that will permit them to participate in scientific discussion in our rapidly changing knowledge-based society, prepare for further study or a career in fields where a knowledge of science will be useful, and become lifelong learners in science and technology. Teachers should adopt an extensive repertoire of pedagogical approaches to achieve the wide range of curriculum aims and learning targets.

The following sections outline the current view of knowledge in science and how students learn. Based on these, learning and teaching approaches and strategies and the establishment of a learning environment conducive to promoting student learning are discussed.

4.2 Knowledge and Learning

4.2.1 Views of knowledge in science

Science is not just a body of conceptual and theoretical knowledge, but a creative endeavour by scientists to understand phenomena in Nature. Scientific knowledge is generated through scientists' insightful observations and systematic inquiry. The community of science allows scientists to exchange their findings and thoughts, and to review and assess the conclusions of others. **An understanding of science, therefore, requires an appreciation of its history and development, an understanding of the nature and methods of science, the development of a certain level of expertise in scientific inquiry, and the acquisition of scientific knowledge**. So, on the one hand, students have to acquire a collection of well-established facts, strict definitions and non-negotiable rules (e.g. safety procedures) and algorithms (e.g. symbols, conventions and certain experimental procedures) – and on the other to develop the sort of thinking and methodology through which the knowledge of science is generated.

Science requires creativity and personal involvement, and is constructed by a community of people. Theories are not out there simply waiting to be discovered by observing Nature; they are human constructions and shape the way in which we observe the world. **Being introduced into the scientific community requires that students learn something about scientific discourse**. It is important that learning activities help students to think, talk and write about science, so that they gain the vocabulary, syntax, and rhetoric – the discourse – needed to understand the knowledge structures associated with the subject.

4.2.2 Views of learning

The provision of a learning environment, which takes account of the characteristics of the students, is of paramount importance. Below are some current understanding of how students learn in science, and how we can help them to learn more effectively:

- Learning science involves being introduced to the ways of thinking and communicating used in the scientific community. These are based on particular scientific concepts and modes of explaining. It is important to guide students into the development of the language of science.

- The development of intellectual competence requires more than the accumulation of discrete pieces of information. The content in a domain of knowledge is embedded in coherent structures; and the ability to discern and build on those structures is what distinguishes experts from novices. It is important to promote **an holistic view of science**. Unifying concepts and the nature of science are introduced in the Integrated Science curriculum to familiarise students with the structure of the knowledge in the area. Helping students to recognise and build on this structure can promote transfer of learning to new situations.
- Students come to school with preconceptions about how the world works. If that initial understanding is not engaged, students may be unable to grasp new information and concepts; or they may just learn them for the purpose of passing tests, but fail to integrate the new information into their framework of existing knowledge and apply it, so making it their own. It is important to find out what constitutes a student's understanding about the world and help them move to a more sophisticated level of understanding.
- Active learning also involves students in **doing science** – identifying problems, framing questions and working with the teacher as a consultant to explore, and develop possible solutions. Students should be encouraged to carry out **scientific inquiries** by themselves, and the problems to be investigated should relate to what they wish to know about or solve. Students should shape the questions themselves so that the investigations become their tasks – in this way, they feel in control of their learning and more fully involved in it.
- Science learning originates in **interaction**. Language is central to teaching and learning science. Language provides the means by which new ideas are first introduced and rehearsed, and the tools for student thinking: 'scientific talk' provides the conceptual tools for 'thinking about science'. One way of facilitating learning is to adopt more group-based approaches. Group work creates **a forum for challenge, debate and the construction of meaning.** It also leads to the expression of alternative views about phenomena and issues**.**

Current theories of learning and science education suggest that knowledge is not merely actively built by the learner working alone, but requires the **co-construction of meaning in a community**. The establishment of a learning environment that is open and supportive, with the teacher as a consultant, helps students to put together conceptual frameworks and develop their own understanding of the world around them.

4.3 Approaches and Strategies

Different students have different abilities and learning styles and so no single teaching approach can meet all their needs. The following approaches are commonly used in the science classrooms and can complement each other:

- **Teaching as direct instruction**
  Teaching as direct instruction is linked with a belief in learning as a faithful reproduction of knowledge input. To gain the full benefits from direct instruction, quality teacher talk and interaction with the students (including questioning and providing feedback) are essential to ensure that students understand and can express the knowledge that has been transmitted. This approach is also relevant to contexts in which the teacher, as the expert in scientific skills, acts as the transmitter of knowledge or as a model for students to follow.
- **Teaching as inquiry**
  Teaching as inquiry derives from the belief that learning is best brought about by student inquiry. It is manifested in activities in which students undertake inquiry to develop knowledge and understanding, in order to make better sense of the world. Students may inquire into a phenomenon through 'hands-on' investigation in which they identify questions, formulate procedures, test hypotheses, gather and analyse data, and draw conclusions. Or they may examine second-hand information to identify facts and inferences, clarify cause-and-effect relationships and develop their own understanding of an issue.
- **Teaching as co-construction**
  Teaching as co-construction is linked to the belief that learning is best seen as a social act involving co-construction of knowledge in a group, rather than transmission from teacher to student, or acquisition through individual student inquiry. Students learn by constructing knowledge through interaction with their peers and teachers. Through co-construction, students are enabled to develop social skills and abilities, to organise their thoughts, and to develop rational arguments. Teachers are partners in students' learning. Through providing conceptual tools to students (e.g. unifying concepts in science), teachers help them to relate their learning to a framework based on which they can construct new knowledge.

The above three teaching approaches can be viewed as a continuum along which the role of the teacher varies, but is not diminished. Students should be encouraged to become more independent in their learning as they mature, so that they can develop into lifelong learners.

In organising the learning and teaching for the Integrated Science curriculum, a teacher should take into account students' prior knowledge as well as their abilities and learning styles: a variety of learning and teaching activities should be used to meet the different objectives of individual lessons and the needs of different students. The most important guideline for choosing suitable strategies is their 'fitness for purpose'.

4.3.1 Guiding students into the development of the language of science

Scientists help us to make sense of the natural world by producing objective knowledge about it. The language of science – a tool the scientific community uses for communicating, understanding and developing scientific ideas, concepts and theories – is different from everyday language. There are scientific terms (e.g. gene, molecule, force) that are carefully and unambiguously defined within conceptual structures (e.g. theories and models); and there are symbols and notations designated for specific materials, phenomena and theoretical constructs (e.g. chemical symbols and formulas), and perhaps most importantly there are particular ways of setting out scientific texts that explain how investigations were carried out or that report and explain phenomena. The science teacher and the language teacher should work hand in hand to develop good practices for initiating the students into scientific discourse in both subject areas. The Knowledge Strand in the English curriculum is specifically designed to link with content subjects (such as Integrated Science) across the curriculum.

4.3.2 Promoting a holistic view and understanding of science

4.3.2.1 Engaging students in active learning

Learning requires the active involvement of students in learning tasks arranged by teachers; and how active they become may be determined in part by their prior knowledge and motivation. **Scaffolding**, which involves teachers in providing pedagogical support to learners is required when presenting students with a task that is just beyond their reach. In arranging learning tasks for each module, teachers should take into consideration the students' **prior knowledge and skills** and tailor the tasks so that they find them challenging and where necessary provide them with scaffolding such as leading questions, guidelines etc. For example, having learned about how visible light travels and reflects in Secondary 3, students will be eager to participate in investigating how invisible microwaves, which they come across in everyday life, travel and interact with matter (Module C7).

4.3.2.2 Facilitating students' concept-building

- The abstract nature of scientific concepts makes the learning of science difficult for some students. The use of IT, such as computer simulations and modelling can help students to visualise abstract scientific constructs (e.g. the molecular shape of water in Module C1), and understand scientific concepts and theories (e.g. the surface-atmosphere radiation exchange in Module E1, and the development of drug resistance in Module E2).
- Students' conceptions about natural phenomena influence their learning, as they build new knowledge and understanding on the basis of what they already know and believe. They formulate new knowledge by modifying and refining their current concepts and by adding new concepts to their existing knowledge. When faced with a scientifically-oriented question, problem, or phenomenon, the teacher should use activities that **tap the preconceptions of the learners**. For example, before performing the slinky experiments (Module C7), teachers may ask the students to **predict** what will happen when two pulses of different amplitudes coming from opposite directions meet, and **explain** their predictions. This engages the students actively in the experiments, as they will be interested in finding out whether their predictions and explanations are correct. The failure of their preconceived ideas in predicting and explaining the phenomenon, and the discovery of an alternative explanation after a scientific inquiry can bring about a conceptual change among the students.
- Learning is mediated through interaction. The learning experiences provided should include opportunities for concept-building by individuals as well as collaborative learning with peers. Teachers can ask students to debate an environmental issue of concern to them, or play the roles of the different parties involved in it (Module C6). In these activities, students have to plan, make use of the resources available to them from various sources, evaluate the information using the scientific knowledge they have learned, employ their inquiry abilities to address the issue, and seek help from one another. In the process, students will come to consolidate their ideas on the issue or develop a new way of thinking about it through exploration and interaction with their classmates. This is conducive to effective learning as students have to reorganise the deep structure of their thinking processes.
- A broad understanding of the main scientific explanations provides a framework for making sense of the world. Learning activities should be arranged in a way which helps students to **understand scientific knowledge, not in isolation, but in relation to its unifying concepts**. Through such unifying concepts students learn beyond the facts and see an overarching coherence in their understanding of the natural world. Our body (Module C2) and the Earth (Module C6) are introduced to

students as organised systems maintained by their different components. In such cases, teachers can use a systems analysis approach in designing the learning and teaching activities. That is, activities should be designed to help students to: identify the components of these systems and their boundaries, and to find out how the components are related and interact to shape the properties of the systems (which may be different from those of individual components) and maintain the proper functioning of the systems. With an understanding of the interactions of the components in the systems, students are able to make informed decisions on, for example, health and environmental issues.

4.3.2.3 Facilitating students' learning through scientific inquiry

- **Scientific inquiry** allows scientists to actively create, modify, or discard an explanation for a phenomenon. Students should learn how to carry out scientific inquiry, not just learn about the facts/concepts which are the products of inquiry. Conceived of in this way, students should be given sufficient opportunities to acquire the science process skills, including, observing, classifying, measuring, handling and equipment apparatus, inferring, predicting, hypothesising, interpreting and analysing, in experimental work in the laboratory. The mastery of these science process skills will enable students to carry out scientific inquiry by themselves.
- Scientists are good models for students, and asking students to repeat the experiments of some scientists helps them to experience the systematic approach scientists used to answer their questions. For example, in Module C5, students may share the curiosity of Oersted when told about his serendipitous discovery that a compass flicked when a current was passed through a wire. In repeating Oersted's experiments, students work as scientists do – obtaining empirical evidence from experiments, making observations, analysing evidence critically, and making careful inferences conducive to scientific explanations. As some experiments which led to significant discoveries cannot be repeated in school laboratories, asking students to read stories on specific themes is a good strategy. For instance, the story of how the modern atomic model has evolved and how this model contributed to the refinement of the periodic table (Module C4) can enable students to appreciate that the periodic table is a co-constructed product of systematic inquiry by scientists over time.
- Through engaging students in scientific inquiries or exposing them to episodes of history of science, students will develop a better understanding of the nature of science – the values and assumptions inherent to science, scientific knowledge, and the development of scientific knowledge.

4.3.2.4 Promoting scientific attitudes, scientific thinking and the scientific practices

Science education aims at introducing students to the beliefs, practices, values and styles of discourse in the community of scientists, to allow them to **participate intelligently in public discourse and debate** about important issues that involve science, technology and society. In addition to equipping students with the scientific knowledge to decipher technical articles in journals, magazines and the Internet, learning activities should emphasise the development of logical thinking and help students to be critical about 'evidence' and claims in science-related matters.

- A crucial part of science education involves understanding the particular rationality that scientists employ in generating and validating scientific knowledge. Introducing students to stories of how scientists do science (e.g. Modules C4, C5, C7 and C8) can illustrate the inductive and deductive logic used by scientists to generate scientific knowledge. As a result, students will come to appreciate the tentative nature of scientific knowledge and develop desirable scientific attitudes, such as being critical and yet open to new evidence.
- Students need to practise the use of logic in doing science. They should be provided with opportunities to analyse and make deductions, using the results of investigations of their own or by other scientists. While explaining Mendel's Laws of Inheritance (Module C8) can help students to understand heredity and variation, it is the 'hands-on' experience of analysing empirical data and deducing the Laws that helps to nurture the scientific habit of mind. Also, students will be inspired by Mendel's creativity in suggesting the Laws of Inheritance well before the existence of genes was realised.
- Science demands and relies on evidence. Students should be given opportunities to evaluate claims and theories suggested by scientists, with evidence, in groups. The discovery of the different elements discussed in Module C4 showed that Thales's conception of water as the 'single universal element' from which all things were constructed was wrong. However, scientists still regard water a very important 'element', they now suggest that it is in water that life begins. Through an information search, students can scrutinise the relevant scientific evidence – and, in the light of what they learned about water in Module C1 and the information they have gathered, they can discuss and evaluate the arguments for or against the claim. Through this and similar activities, students' scientific literacy is enhanced, and they become more capable of analysing science- and technology-related issues before making decisions.

4.3.3 Promoting learning to learn

4.3.3.1 Facilitating self-regulated learning

Effective learning requires that students take control of their own learning. Through scaffolding (such as instructional support and guidance on experimental procedures) provided by the teachers, students are assisted to develop their ability to question, reason and think critically about scientific phenomena. **Scaffolding should be removed gradually, with students taking increasing control of their own learning**. In Module C2, students are required to construct concept maps to show the mechanisms of body temperature and blood glucose regulation. Teacher assistance is expected when the construction and use of concept maps is first introduced, but this support should be reduced as students progress through the module. For instance, after equipping students with some knowledge on nervous coordination and mental health, the teacher should encourage students to explore the scientific basis of mental illnesses of interest to them. In carrying out such investigations, students should employ a range of approaches and select appropriate reference sources, working both on their own and in collaboration with others. They should also engage in critical evaluation of the evidence they have collected and the conclusions they have drawn. In this way, they will also learn to communicate their ideas clearly and precisely.

4.3.3.2 Preparing students for active participation as citizens

Studying science should not be confined to learning from standard science textbooks. Science topics should be structured in ways which highlight the **relevance and meaning of science content to students as citizens**. Learning activities should require students to: draw information from sources; employ the skills of carrying out quantitative or qualitative inquiries; report their findings or other information in appropriate ways; and present their conclusions or thoughts for a range of purposes in different contexts, and for a variety of audiences. It is desirable to provide learning experiences which engage students in the following ways:

Drawing upon sources of information, such as:	**Using science language for the purposes of**:	**Presenting information in forms such as**:
• Observations • Experiments • Textbooks • Product brochures/ advertisements • Magazines/newspapers • Videos/ films • The Internet	• Reporting results • Formulating hypotheses • Designing experiments • Justifying a stance • Interpreting a theory • Drawing conclusions • Predicting the results of experiments	• Laboratory/field notes • Reports on experiments • Learning journals • Oral presentations • Charts/graphs • Models • Photographs

Figure 4.2 Preparing students for active participation as citizens

To help students to explore contemporary issues related to science and technology, teachers can set up a 'Science Corner' in the classroom or the laboratory to display interesting science articles of appropriate breadth and depth from various sources. This also helps to nurture good reading habits. As students develop the ability to read, interpret, analyse and communicate new scientific concepts and ideas, they will see reading as an important means of keeping in touch with the latest developments in science.

To sum up, it is important for teachers to use a wide variety of learning and teaching activities to help students attain the different learning targets of the curriculum. Figure 4.3 lists a range of learning and teaching activities commonly used in science classrooms, which require different levels of student engagement and suit their varied learning styles. Moreover, teachers should note that students may achieve multiple learning targets during the same learning process.

Teacher-centred	◄	————————	►	**Student-centred**
Direct instruction	Interactive teaching	Inquiry	Co-construction	Individualisation
• Explaining • Demonstrating • Video shows	• Teacher questioning • Whole-class discussion • Group discussion • Visits	• Practical work • Scientific investigations • Problem-solving • Simulation and modelling	• Role-play • Debates • Project work • Discussion forums	• Reading • Information search • Writing learning journals • Constructing concept maps

Figure 4.3 Learning and teaching activities in science

4.4 Interaction

Interaction involves communication between teachers and students, as well as among students. Lessons should be planned stage by stage to ensure that the interaction which takes place is of a high quality.

4.4.1 Building an environment that supports learning

A flexible use of learning and teaching strategies and a well-structured classroom with quality interaction (both teacher-student and student-student) are crucial for learning to take place. Noted below are some features of classrooms that help to promote students' active participation as members of a learning community:

- a suitable physical setting which allows a variety of types of learning activity (e.g. laboratory activities, whole-class discussion, group work and individual work) to take place;
- explicit sharing of the learning objectives of lessons (e.g. by writing them clearly on the board), with teachers explaining their relevance, and the position of the lesson in the learning of the whole topic;
- clear and specific success criteria generated from the learning objectives through guided discussion (e.g. What do you think should be included in a full laboratory report?);
- learning activities that are challenging and motivating to promote meaning-making among students;
- opportunities for students to present and exchange ideas (e.g. students in groups design experiments and post their proposals on the board for comment);
- timely and specific feedback to the class, groups, and individual students;
- time for plenary sessions at the end of lessons for students to recapitulate what has been learned, check that the lesson objectives have been achieved and plan for the next step in learning.

4.4.2 An interactive classroom

Maintaining an open and inviting atmosphere, in which students can express their thoughts freely without being afraid of making mistakes, is of paramount importance for effective learning and teaching. Figure 4.4 outlines some of the features of an interactive classroom:

Teachers	**Students**
• Demonstrate the use of science language, conventions and syntax in asking questions, elaborating and giving feedback – making explicit reference to the distinctive features of the language used (e.g. when to use the verbs 'prove' and 'support'; when to use the present tense and reported speech) • Ask questions that: – elicit students' understanding – challenge students to think for themselves – lead students to articulate their ideas	• Respond to questions with thoughtful answers; contribute to a contextual dialogue • Communicate ideas to others using a variety of means (e.g. models, drawings, graphs) and in proper science language • Ask questions and provide explanations • Participate in activities in which they argue, reason and justify with evidence in science language • Listen and respond actively to their peers with quality feedback

• Allow suitable 'wait time' • Provide evaluative feedback which – diagnoses and clarifies misunderstandings – promotes self-regulated learning by eliciting and spelling out students' lines of thinking – identifies strengths and weaknesses, instead of just showing the 'correct way' – tells students what more needs to be done, and how to do it • Use prompts not only to cue 'correct answers' but also to lead to reflection on procedures and methods • Shift from brief and random interactions to longer and more sustained ones.	

Figure 4.4 Characteristics of an interactive classroom

Through participating in a rich array of classroom activities, students can develop a repertoire of strategies for 'talking about and doing science' that can be applied in a wide variety of situations in everyday life, and take part in discussing societal issues.

4.5 Catering for Learner Diversity

Students vary greatly in their backgrounds, academic abilities and prior knowledge. Schools should provide opportunities for all students to develop their capacities to the fullest regardless of their differences.

4.5.1 Strategies to cater for learner diversity

4.5.1.1 Catering for students with diverse abilities

Teachers should pay attention to what students bring with them to the lessons. By carefully introducing activities to tap students' different ideas and understandings, and designing ways to allow them to participate in different ways, students will have the opportunity to take on different responsibilities and develop different kinds of expertise.

On the other hand, teachers can group students of similar ability together so that they can provide each group with appropriate challenges and support. In grouping by achievement, teachers should:

- form and reform groups on the basis of students' current performance;
- discourage comparisons between groups, to encourage students to develop 'a whole-class spirit'; and
- ensure that the methods used and the pace are adjusted to fit the needs of groups.

Some practical guidelines for catering flexibly for the needs of students of varied ability are noted below:

- **Adjust the level of scientific skills required**: For example, the sophistication of the skills required for studying the effects of temperature on enzymatic activities in Module C2 can be varied by (a) providing the procedures and using an enzyme with a narrower range of active temperatures or (b) requiring students to design the procedures and compare the effects of temperature on the activities of different enzymes.
- **Adjust the level of language skills required**: For example, the language skills needed for presenting results in relation to the development of the atomic model in Module C4 can be varied by allowing students to use descriptive paragraphs supplemented by diagrams or flow diagrams with simple annotations.
- **Adjust the level of mathematical skills required**: For example, for the unit of velocity, students can grasp m/s more easily than m s^{-1}, and 0.002 is easier to the students than 2×10^{-3}. In addition, using spreadsheets for the calculation of velocity and acceleration from a series of data collected in Module C3 can reduce students' workload in handling numbers.
- **Vary the method for recording and analysing experimental data**: For example, in the analysis of a sprint, students may use video-motion analysis software for plotting different kinds of graphs for analysis or they can plot their own graphs using paper and pen.
- **Vary the pace of learning**: Students can undertake the same set of activities but complete them at a different pace. More time to complete activities, and extra support, should be given to students with lower academic ability.

4.5.1.2 Catering for diverse learning styles

Students vary not only in ability but also in their learning styles, and this can have a considerable influence on their achievement. Information is taken in and processed in different ways – some people are visual learners, some are auditory learners, and some are kinesthetic learners. Where possible, teachers should try to accommodate students' preferred approaches to learning. For example, in studying motion during a sprint (Module C3), kinesthetic learners are likely to learn better by taking a sprint themselves to experience the changes involved, whereas visual learners may benefit more from observing a sprinter's motion or watching it on a video. It may also be possible to allow students to use different presentation methods in reporting their findings. For instance, in an information search on the various influenza pandemics in the 20th century (Module E2), students can be allowed to write a report, draw a comic strip, record a digital audiotape or perform in a role-play.

When used appropriately, information technology (IT) can be very effective in catering for different learning styles. For example, some students who are very quiet and passive during lessons may participate actively and contribute useful ideas in online discussion forums. The multimedia elements offered by IT are particularly useful for learners who prefer visual and auditory approaches to learning. Also, the interactive nature of IT-based resources helps to motivate students to learn, and supports their self-assessment through providing prompt feedback. In addition, IT-assisted learning enables students to extend learning beyond the school timetable and classroom settings. In general, IT can help students to learn in their own ways and at their own pace and, therefore, promote self-regulated learning.

4.5.2 Learning and teaching for students with special educational needs

Based on the principle of 'one curriculum framework for all', students with special educational needs (SEN) are integrated into mainstream schools. To cater for the needs of these students in science learning, teachers can adopt the following strategies:

- Adapt the curriculum appropriately by fine-tuning the learning targets and learning content, so that they can find an appropriate starting point for their learning;
- Focus on using their strengths to build their confidence and maintain motivation (e.g. involving physically disabled students in observing and recording results while others work with equipment);
- Help them to overcome their learning difficulties by making appropriate adjustments to learning materials (e.g. by using enlarged print, simple and consistent language and clear uncluttered illustrations for students with reading or visual difficulties);
- Allow them to produce work, such as reports, in different formats to suit their capabilities (e.g. using computers, in written form, on video and audio tapes);
- Make effective use of classroom helpers and technical support while the students still maintain control of their work;
- Organise some work in groups and in pairs, in which they can demonstrate what they can do;
- Break activities into various smaller tasks with specific learning targets and

achievement standards, so that they can learn step-by-step, and give appropriate help when necessary;

- Match the demands of activities to their level of attainment; and
- Ensure that the pace of lessons takes into account the different speeds at which they work.

Individualised educational plans may be drawn up to cater for the specific needs of students, taking into account the views of various professionals, teachers, parents and the students themselves. Through setting specific learning targets and learning strategies and by regular evaluation of the plans, SEN students can learn more effectively and their potential be fully developed.

4.5.3 Catering for the gifted

The needs of students with a special talent in science should also be catered for. One way of helping them to reach their full potential is through *acceleration*, by allowing such gifted students to move more quickly through the learning process, and perhaps enrol concurrently in other advanced courses, while keeping them with their peers for most classes. Another approach involves *enrichment* – that is, by giving them opportunities for additional, more sophisticated, and more thought-provoking work, but again keeping them with their age-mates in school. They should be involved in more challenging scientific inquiry and be given opportunities to act independently as learners, for example in defining problems, using information sources and evaluating procedures. Gifted students can then regulate their own learning by exploring their own personal interests in learning science.

Working with gifted students requires teachers to be imaginative, flexible and tolerant. They should not focus simply on getting such students to learn more facts, but should encourage abstract thinking, creativity, the reading of high-level and original texts, and self-directed learning.

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Chapter 5 Assessment

This chapter discusses the role of assessment in learning and teaching Integrated Science, the principles that should guide assessment of the subject and the need for both formative and summative assessment. It also provides guidance on internal assessment and details of the public assessment of Integrated Science. Finally, information is given on how standards are established and maintained, and how results are reported with reference to these standards. General guidance on assessment can be found in the ***Senior Secondary Curriculum Guide* (2007)**.

5.1 The Roles of Assessment

Assessment is the practice of collecting evidence of student learning. It is a vital and integral part of classroom instruction, and serves several purposes and audiences.

First and foremost, it gives feedback to students, teachers, schools and parents on the effectiveness of teaching and on students' strengths and weaknesses in learning.

Second, it provides information to schools, school systems, government, tertiary institutions and employers to enable them to monitor standards and to facilitate selection decisions.

The most important role of assessment is in promoting learning and monitoring students' progress. However, in the senior secondary years, the more public roles of assessment for certification and selection come to the fore. Inevitably, these imply high-stakes uses of assessment since the results are typically employed to make critical decisions about individuals that affect their future.

The Hong Kong Diploma of Secondary Education (HKDSE) provides a common end-of-school credential that gives access to university study, work, and further education and training. It summarises student performance in the four core subjects and in various elective subjects, including both discipline-oriented subjects such as Integrated Science and the new Applied Learning courses. It needs to be read together with the other information about students provided in the Student Learning Profile.

5.2 Formative and Summative Assessment

It is useful to distinguish between the two main purposes of assessment, namely 'assessment *for* learning' and 'assessment *of* learning'.

‘Assessment *for* learning’ is concerned with obtaining feedback on learning and teaching, and utilising this to make learning more effective and to introduce any necessary changes to teaching strategies. We refer to this kind of assessment as ‘formative assessment’ because it is all about forming or shaping learning and teaching. Formative assessment should take place on a daily basis and typically involves close attention to small ‘chunks’ of learning.

‘Assessment *of* learning’ is concerned with determining progress in learning, and is referred to as ‘summative’ assessment because it is all about summarising how much learning has taken place. Summative assessment is normally undertaken at the conclusion of a significant period of instruction (e.g. at the end of the year, or of a Key Stage of schooling) and reviews much larger ‘chunks’ of learning.

In practice, a sharp distinction cannot always be made between formative and summative assessment, because the same assessment can in some circumstances serve both formative and summative purposes. Teachers can refer to the ***Senior Secondary Curriculum Guide*** **(2007)** for further discussion of formative and summative assessment.

Formative assessment should be distinguished from continuous assessment. The former refers to the provision of feedback to improve learning and teaching based on formal or informal assessment of student performance, while the latter refers to the assessment of students’ on-going work and may involve no provision of feedback that helps to promote better learning and teaching. For example, accumulating results in class tests carried out on a weekly basis, without giving students constructive feedback, may neither be effective formative assessment nor meaningful summative assessment.

There are good educational reasons why formative assessment should be given more attention and accorded a higher status than summative assessment, on which schools tended to place a greater emphasis in the past. There is research evidence on the beneficial effects of formative assessment when used for refining instructional decision-making in teaching and generating feedback to improve learning. For this reason, the CDC report ***Learning to Learn – The Way Forward in Curriculum Development*** **(2001)** recommended that there should be a change in assessment practices, with schools placing due emphasis on formative assessment to make assessment *for* learning an integral part of classroom teaching.

It is recognised, however, that the primary purpose of public assessment, which includes both public examinations and moderated school-based assessment (SBA), is to provide summative assessments of the learning of each student. While it is desirable that students are exposed to SBA tasks in a low-stakes context and benefit from practice and experience with the tasks (i.e.

for formative assessment purposes) without penalty, similar tasks will need to be administered subsequently as part of the public assessment to generate marks to summarise the learning of students (i.e. for summative assessment purposes).

Another distinction to be made is between internal assessment and public assessment. Internal assessment refers to the assessment practices that teachers and schools employ as part of the ongoing learning and teaching process during the three years of senior secondary studies. In contrast, public assessment refers to the assessment conducted as part of the assessment process in place for all schools. Within the context of the HKDSE, public assessment includes both the public examinations and the moderated SBA conducted or supervised by the HKEAA. On balance, internal assessment should be more formative, whereas public assessment tends to be more summative. Nevertheless, this need not be seen as a simple dichotomy. The inclusion of SBA in public assessment is an attempt to enhance formative assessment or assessment *for* learning within the context of the HKDSE.

5.3 Assessment Objectives

The assessment objectives are closely aligned with the curriculum framework and the broad learning outcomes presented in earlier chapters.

The learning objectives to be assessed in Integrated Science are to evaluate students' ability to:

(a) recall and show understanding of facts, concepts and principles of science, and the relationships between different topic areas in the curriculum framework;
(b) apply scientific knowledge, concepts and principles to explain phenomena and observations, and to solve problems;
(c) formulate working hypotheses, and plan and perform tests for them;
(d) demonstrate practical skills related to the study of science;
(e) present data in various forms, such as tables, graphs, charts, drawings, diagrams, and transpose them from one form into another;
(f) analyse and interpret both numerical and non-numerical data in forms such as continuous prose, diagrams, photographs, charts and graphs – and make inferences and logical deductions, and draw conclusions from them;
(g) formulate arguments, justify claims, evaluate evidence and detect errors;
(h) select, synthesise and communicate ideas and information clearly, precisely and logically;

(i) demonstrate understanding of the applications of science to daily life and the contributions of science to the modern world;
(j) show awareness of the ethical, moral, social, economic and technological implications of science, and critically evaluate science-related issues; and
(k) make suggestions, choices and judgments based on scientific knowledge and principles.

5.4 Internal Assessment

This section presents guiding principles for the design of internal assessment, and some common assessment practices for Integrated Science for use in schools. Some of these principles are common to both internal and public assessment.

5.4.1 Guiding principles

Internal assessment practices should be aligned with the curriculum, teaching progression, student abilities and school context. The information collected will help to motivate, promote and monitor student learning, and will also help teachers to find ways of promoting more effective learning and teaching.

(a) ***Alignment with the learning objectives***

A range of assessment practices should be used to assess comprehensively the achievement of different learning objectives for whole-person development, which include: knowledge and understanding of principles and concepts in science; scientific skills and processes; and positive values and attitudes. The weighting given to different areas in assessment should be discussed and agreed among teachers. The assessment purposes and criteria should also be made known to students so that they can have a full understanding of what is expected of them.

(b) ***Catering for the range of student ability***

Assessment at different levels of difficulty and in diverse modes should be used to cater for students with different aptitudes and abilities. This helps to ensure that the more able students are challenged to develop their full potential, and the less able ones are encouraged to sustain their interest and succeed in learning.

(c) ***Tracking progress over time***

As internal assessment should not be a one-off exercise, schools are encouraged to use practices that can track learning progress over time (e.g. portfolios). Assessment practices of this kind allow students to set their own incremental targets and manage their pace of learning, which will have a positive impact on their commitment to learn.

(d) ***Timely and encouraging feedback***

Teachers should provide timely and encouraging feedback through a variety of means, such as constructive verbal comments during classroom activities and written remarks on assignments. Good feedback helps students to sustain their momentum in learning, and to identify their strengths and weaknesses.

(e) ***Making reference to the school's context***

As learning is more meaningful when the content or process is linked to a setting which is familiar to students, schools are encouraged to design some assessment tasks that make reference to the school's own context (e.g. its location, relationship with the community, and mission).

(f) ***Making reference to current progress in student learning***

Internal assessment tasks should be designed with reference to students' current progress, as this helps to overcome obstacles that may have a cumulative negative impact on learning. Teachers should be mindful in particular of concepts and skills which form the basis for further development in learning.

(g) ***Feedback from peers and from the students themselves***

In addition to giving feedback, teachers should also provide opportunities for peer assessment and self-assessment in student learning. The former enables students to learn among themselves, and the latter promotes reflective thinking which is vital for students' lifelong learning.

(h) ***Appropriate use of assessment information to provide feedback***

Internal assessment provides a rich source of data for providing evidence-based feedback on learning in a formative manner.

5.4.2 Internal assessment practices

A range of assessment practices suited to Integrated Science, such as assignments, practical work and scientific investigations, oral questioning and projects, should be used to promote the attainment of the various learning outcomes. However, teachers should note that these practices should be an integral part of learning and teaching, not 'add-on' activities.

Assignments

Assignments are a valuable and widely used assessment tool that reflects students' efforts, achievements, strengths and weaknesses over time. A variety of assignment tasks – such as exercises, essays, designing posters or leaflets, and model construction – can be used to allow students to demonstrate their understanding and creative ideas. The assignment tasks should be aligned with the learning objectives, teaching strategies and learning activities. Teachers can ask students to select a topic of interest, search for information, summarise their findings and devise their own ways of presenting their work (e.g. role-play, essays, poster designs or presentation slides). Teachers should pay close attention to students' organisation of the materials, the language they use, the breadth and depth of their treatment, and the clarity with which they explain concepts. The scores or grades for assignments can be used as part of the record of students' progress; and the comments on their work, with suggestions for improvement, provide valuable feedback to them. Assignments can also help in evaluating the effectiveness of teaching by providing feedback upon which teachers can set further operational targets for students and make reasonable adjustments in their teaching strategies.

Practical work and scientific investigations

Practical work and scientific investigations are common activities in the learning and teaching of science subjects. They offer students 'hands-on' experience of exploring, and opportunities to show their interest, ingenuity and perseverance. In scientific investigations, teachers can first pose a problem and ask students to devise a plan and suggest appropriate experimental procedures for solving it – and the design of the investigations can then be discussed and, if necessary, modified. During such sessions, teachers can observe students' practical skills and provide feedback on how the experiment/investigation might be improved. Marking students' laboratory reports can provide a more complete picture of students' understanding of the scientific concepts and principles involved, as well as their ability to handle and interpret data obtained in investigations.

Oral questioning

Oral questioning can provide teachers with specific information on how the students think in certain situations, as their responses often provide clues to their level of understanding, attitudes and abilities. Teachers can use a wide range of questions, from those which involve fact-finding, problem-posing, and reason-seeking to more demanding ones which promote higher levels of thinking and allow for a variety of acceptable responses. This can be a valuable supplement to conventional assessment methods.

Projects

A project can be any piece of extended work on any topic. Asking students to carry out project work provides an opportunity for them to study a topic of interest in depth. Teachers can set project work for students based on the activities suggested in each module, and develop appropriate criteria to assess the ideas being formed and skills being developed by students during the process.

5.5 Public Assessment

5.5.1 Guiding principles

Some principles guiding public assessment are outlined below for teachers' reference.

(a) ***Alignment with the curriculum***

The outcomes that are assessed and examined through the HKDSE should be aligned with the aims, objectives and intended learning outcomes of the senior secondary curriculum. To enhance the validity of public assessment, the assessment procedures should address the range of valued learning outcomes, and not just those that are assessable through external written examinations.

The public assessment for Integrated Science will place emphasis on testing candidates' ability to apply and integrate knowledge in authentic and novel situations. In addition, the SBA component extends the public assessment to include valuable scientific investigative skills and generic skills such as creativity, critical thinking, communication and problem-solving.

(b) ***Fairness, objectivity and reliability***

Students should be assessed in ways that are fair and are not biased against particular groups of students. A characteristic of fair assessment is that it is objective and under the control of an independent examining authority that is impartial and open to public scrutiny. Fairness also implies that assessments provide a reliable measure of each student's performance in a given subject so that, if they were to be repeated, very similar results would be obtained.

(c) ***Inclusiveness***

The current HKALE is designed for a relatively elite group of students, most of whom aspire to university study. However, the new assessments and examinations aim to accommodate the full spectrum of student aptitude and ability.

Integrated Science is a new subject, with a curriculum designed to build on the science knowledge students have gained in S1 to S3. It also strikes a balance between breadth and depth of scientific understanding, and between theoretical and applied learning. The public examination will contain questions which test candidates' knowledge of the foundations and selected areas in science, and assess higher-order thinking skills. At the same time, the SBA component offers room for a wide range of activities to cater for the differing preferences and readiness of students and/or schools.

(d) ***Standards-referencing***

The new system will be 'standards-referenced', i.e. student performance will be matched against standards, which indicate what students have to know and be able to do to merit a certain level of performance. Level descriptors will be developed for Integrated Science in due course to provide information about the typical performance of candidates at the different levels.

(e) ***Informativeness***

The new qualification and the associated assessment and examinations system should provide useful information to all parties. First, it should provide feedback to students on their performance and to teachers and schools on the quality of the teaching provided. Second, it should communicate to parents, tertiary institutions, employers and the public at large what it is that students know and are able to do, in terms of how their performance matches with the standards. Third, it needs to facilitate selection decisions that are fair and defensible.

5.5.2 Assessment design

The assessment design is subject to continual refinement in the light of feedback. Full details will be provided in other supplementary documents, in particular the approved Regulations and Assessment Frameworks for the year of the examination.

Component	Outline		Weighting	Duration
Public Examination	Paper 1	Questions on the Compulsory Part	45%	2 hours
	Paper 2 Section A Section B	 Multiple-choice questions on the Compulsory Part Questions on the Elective Part (a choice of two out of three electives)	35%	1½ hours
School-based assessment* (SBA)	Practical related tasks[1] and non-practical related tasks		20%	

Table 5.1 An outline of the assessment design

* To allow time for teachers to familiarise themselves with the administration of SBA and to alleviate the workload of teachers in the first two years of implementation of the new curriculum, the following implementation strategy of SBA will be adopted:

Year of examination	Implementation of SBA
2012	Schools are required to submit SBA marks for the practical related component only. The mark of this component will contribute to 20% of the final subject mark.
2013	Schools are required to submit SBA marks for the practical related component only. The mark of this component will contribute to 20% of the final subject mark.
2014 and thereafter	Schools have to submit SBA marks for both the practical and non-practical related components. The marks of both components will contribute to 20% of the final subject mark.

5.5.3 Public examinations

[1] Practical related tasks are activities that require the use of science apparatus and fieldwork.

The overall aim of the public examination is to assess candidates' knowledge and understanding in different areas of science, and their ability to apply this to familiar and unfamiliar situations.

Various kinds of items will be used to assess students' performance in a broad range of skills and abilities. The item types, which will include multiple-choice questions, structured questions, data-response questions and short essays, are similar to those currently adopted in the HKCE and HKAL examinations. Specimen papers will be provided to schools by the HKEAA to illustrate the format of the examination and the standards at which the questions are pitched.

5.5.4 School-based assessment (SBA)

In the context of public assessment, SBA refers to assessments administered in schools and marked by the students' own teachers. The primary rationale for SBA in Integrated Science is to enhance the validity of the assessment by including the assessment of students' practical and generic skills.

There are, however, some additional reasons for SBA. For example, it reduces dependence on the results of public examinations, which may not always provide the most reliable indication of the actual abilities of candidates. Obtaining assessments based on student performance over an extended period of time and developed by those who know the students best – their subject teachers – provides a more *reliable* assessment of each student.

Another reason for including SBA is to promote a *positive* '*backwash effect*' *on students, teachers and school staff*. Within Integrated Science, SBA can serve to motivate students by requiring them to engage in meaningful activities. For teachers, it can reinforce curriculum aims and good teaching practice, and provide structure and significance to an activity they are involved in on a daily basis, namely assessing their own students.

The SBA for Integrated Science comprises two components: assessment of (a) practical related tasks and (b) non-practical related tasks.

(a) ***Practical related tasks***

Students are required to perform a stipulated number of pieces of practical work or investigations. They should be integrated closely with the curriculum content and form a part of the normal learning and teaching process. In investigative work, students are required to:

design and perform investigations; present, interpret and discuss their findings; and draw appropriate conclusions. They are expected to make use of their knowledge and understanding of science in performing these tasks, through which their practical, process and generic skills will be developed and assessed.

(b) ***Non-practical related tasks***

Non-practical related tasks are included to broaden the scope of assessment in SBA and enhance the integration of the curriculum, teaching and assessment. To this end, the tasks adopted should cover one or more of the curriculum content areas and one or more of the generic skills such as creativity, critical thinking skills, communication skills and problem-solving skills. Examples of such tasks include: oral or written presentation of an information search; reporting on an investigation project; writing articles or designing posters on scientific issues; and building models or using IT tools to illustrate scientific concepts. Teachers can adopt different means of assessing the abilities of their students as appropriate.

It should be noted that SBA is not an 'add-on' element in the curriculum. The modes of SBA above are normal in-class and out-of-class activities suggested in the curriculum. The requirement to implement the SBA will take into consideration the wide range of student ability and effort will be made to avoid unduly increasing the workload of both teachers and students. Detailed information on the requirements and implementation of the SBA and samples of assessment tasks will be provided to teachers by the HKEAA.

5.5.5 Standards and the reporting of results

The HKDSE will make use of standards-referenced reporting of assessments. What this means is that candidates' levels of performance will be reported with reference to a set of standards as defined by cut scores on the variable or scale for a given subject. Standards referencing relates to the way in which results are reported and does not involve any changes in how teachers or examiners mark student work. The set of standards for a given subject can be represented diagrammatically as shown in Figure 5.1.

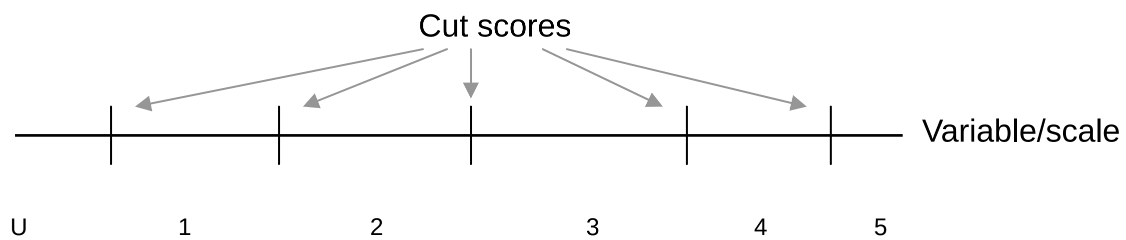


Figure 5.1 Defining levels of performance via cut scores on the variable or scale for a given subject

Within the context of the HKDSE there will be five cut scores, which will be used to distinguish five levels of performance (1-5), with 5 being the highest. A performance below the threshold cut score for Level 1 will be labelled as 'Unclassified' (U).

For each of the five levels, a set of written descriptors will be developed that describe what the typical candidate performing at this level is able to do. The principle behind these descriptors is that they describe what typical candidates *can* do, not what they *cannot* do. In other words, they describe performance in positive rather than negative terms. These descriptors will necessarily represent 'on-average' statements and may not apply precisely to individuals, whose performance within a subject may be variable and span two or more levels. Samples of students' work at various levels of attainment may be used to illustrate the standards expected of them. These samples, when used together with the grade descriptors, will help to clarify the standards expected at the various levels of attainment.

In setting standards for the HKDSE, Levels 4 and 5 will be set with reference to the standards achieved by students awarded grades A-D in the current HKALE. It needs to be stressed, however, that the intention is that the standards will remain constant over time – not the percentages awarded different levels, as these are free to vary in line with variations in overall student performance. Referencing Levels 4 and 5 to the standards associated with the old grades A-D is important for ensuring a degree of continuity with past practice, for facilitating tertiary selection and for maintaining international recognition.

The overall level awarded to each candidate will be made up of results in both the public examination and the SBA. SBA results for Integrated Science will be moderated to adjust for differences among schools in marking standards, while preserving the rank ordering of students as determined by the school.

To maintain current levels of discrimination for selection purposes, the Level 5 candidates with the best performance will have their results annotated with the symbols ** and the next top group with the symbol *. The level awarded to each candidate will be recorded on the Diploma. There will also be a Statement of Results which will in addition provide level descriptors.

Chapter 6 Learning and Teaching Resources

This chapter discusses the importance of selecting and making effective use of learning and teaching resources, including textbooks, to enhance student learning. Schools need to select, adapt and, where appropriate, develop the relevant resources to support student learning.

6.1 Purpose and Function of Learning and Teaching Resources

Learning resources that provide students with experiences of the world outside the school and support them in developing abstract ideas and concepts are particularly useful for promoting independent learning. Resources on the Internet enable students to keep abreast of the latest scientific and technological developments. Teachers are encouraged to utilise various types of resources in their lessons and students may also use them for independent study, with guidance from their teachers. If used effectively, learning and teaching resources help students to construct knowledge for themselves, and develop the learning strategies, generic skills, values and attitudes they need, thus laying a solid foundation for lifelong learning.

6.2 Guiding Principles

In order to meet the different objectives of individual lessons, different learning and teaching resources have to be used. The most important guideline for choosing learning and teaching resources is again 'fitness for purpose'. Learning and teaching resources for science should be selected to meet the educational needs and abilities of students. They should:

- provide a sense of purpose and direction for learning;
- address students' prior knowledge;
- provide students with a variety of phenomena and help them to understand how the phenomena relate to scientific ideas;
- guide students' interpretation and reasoning;
- provide practice in using scientific ideas;
- provide assessment tasks and criteria for monitoring student progress; and
- encourage students to explore science beyond the classroom.

6.3 Types of Resources

6.3.1 Textbooks

Textbooks have a major role to play in helping students to learn key ideas and consolidate learning experiences. They should also support student-centred learning and help students to construct models, theories and understandings for themselves.

(a) Selection of textbooks

Schools should choose science textbooks that will enhance the motivation and learning of students. The following characteristics should be considered when choosing them:

- whether the approach and coverage of the textbooks promotes development of the knowledge, skills, values and attitudes promoted in the curriculum;
- the suitability of the learning content;
- the quality of the language used;
- the appropriateness of the learning activities;
- whether the examples and illustrations are appropriate and aid learning; and
- the safety aspects of the practical work.

A set of guiding principles has been formulated for the writing, reviewing and selection of quality textbooks. When selecting quality student-centred textbooks for their students, teachers are encouraged to refer to these guidelines under textbook information at http://www.edb.gov.hk/cd.

(b) Flexible use of textbooks

Teachers should use science textbooks flexibly according to the needs, abilities and interests of their students. They should not feel obliged to use a textbook from cover to cover, but are free to select and/or adapt relevant parts and to modify the sequence of topics to suit their teaching purposes. They may consider the following points when using textbooks:

- keep the learning targets and objectives of the curriculum in mind and identify the focus of each module;
- match the content with the science curriculum of the school and ensure that there is a balanced coverage of the learning targets and objectives;
- omit certain parts: the more able students may leave out the easier parts and the less able ones can skip the more difficult parts; and
- adapt the content or the activities where necessary to make them more challenging, to initiate critical and creative thinking in students.

6.3.2 Reference materials

Students should be encouraged to read extensively for better understanding and broadening the scope of their learning. There are many interesting references and stories written for students of all sorts – science enthusiasts who want to read about modern science; students who just like reading good science stories; and even students who do not usually read much but enjoy cartoons and good illustrations. It is important to set up a text-rich environment with ample curriculum-related materials which are appropriate for students' varied cognitive levels, linguistic competence and interests. The habit of reading about science can help kindle a lifelong interest in the subject and its progress.

Resources from the media, including news articles, TV programmes and advertisements are useful authentic learning materials for developing students' ability to make informed decisions and judgments. These learning tools provide different perspectives on science-related issues that are relevant to students, and can develop interest and motivation, consolidate concepts, raise conceptual conflicts and help in evaluating and applying science knowledge. Teachers should make flexible use of these resources for the following purposes:

- as the basis for concept formation and concept mapping activities;
- to provide a pool of information from which students can select when carrying out group activities;
- as the starting point for an investigation – where an activity is used, consider making it more open-ended to provide students with opportunities to extend their investigations; and
- to challenge students. Provide students with resources which involve alternative or conflicting, but justifiable, views on the same topic – for instance on the main source of air pollutants in Hong Kong.

Issues and problems relating to science and its impact on society are reported very frequently in the media. Discussions on related topics in the curriculum can be structured around these media reports (e.g. newspaper articles and videos), as this will make the science content more relevant and so increase students' motivation and interest. There are several good reasons for using such media resources, for example:

- They provide students with information they can use in their studies.
- They can suggest issues and questions for investigation.
- They present a range of viewpoints.
- They raise topical issues of relevance to students' everyday lives.

However, teachers should be aware of the risks associated with the use of resources from the mass media as they may sometimes present inaccurate, biased or out-of-date information and present scientific knowledge in 'black and white' terms, as if there were no doubts about the information. Therefore, these resources need to be examined carefully to ensure that they are appropriate for the learning and teaching intentions.

6.3.3 IT-based resources

With the arrival of the Internet, and the availability of an ever-increasing number of software packages, information technology (IT) now has a significant part to play in science lessons. Possible learning tasks using IT include modelling ideas, searching for information, presenting and communication of information. Furthermore, through the use of data-loggers in experiments, students can be relieved from mechanical and time-consuming work in data collection and graphical presentation of data. They can then have more time to analyse, discuss and evaluate experimental results and to answer 'what if' questions. However, IT-based activities are a means, not an end: simply using IT in lessons is insufficient to bring about learning and develop skills. A clear rationale is needed for incorporating IT into lessons (e.g. where its use is in line with the planned lesson outcomes). Some pedagogical practices in which IT can be used effectively for science learning are noted below.

(a) IT-based resources for concept building

Interactive multi-media resources can link different representations and ways of learning to develop understanding in science. In involving students in contributing actively, these packages may require them to make notes, search for key words, answer questions, give explanations or solve problems. These activities can be done through off-line worksheets or be carried out online as an 'electronic workbook'. Such interactive multi-media resources are especially valuable for students who prefer learning through audio-visual materials; and they can also support individualised learning by allowing students to work on differentiated tasks at their own pace.

(b) IT for learning through inquiry

Certain IT applications help students in scientific inquiry, ranging from performing experiments in the real world to making virtual investigations, for example:

(i) Data-logging

As data-loggers become more user-friendly and the analysing tools more powerful, new opportunities open up for investigative work. Data-loggers should be used in learning activities that help students to interpret and explain data. It is a powerful tool because it:

- provides real-time display of the data collected;
- allows multiple representations of data which is particularly useful in teaching graphing skills;
- allows students to put a greater effort in interpreting scientific phenomena and engaging in activities that promote higher-order thinking skills as the data collection workload is reduced; and
- can provide scaffolds for students in collecting and analysing data.

(ii) Simulation and modelling

Simulation of everyday phenomena is often used to help students visualise abstract concepts but can also be employed to perform scientific investigations. For example, using a computer simulation of the motion of objects under different conditions of friction in Module C3 allows students to predict, test and reflect on the relationship between force and motion. By using simulation, students can perform an unlimited number of these experiments, without having to bother about the quality of the data. To help students get the most out of such simulation programmes, teachers should take note of the following potential difficulties students may face:

- They often do not understand that they should be reflecting upon what they have found.
- They may have difficulty in knowing what they should be giving attention to.
- They are not always good at testing their own hypotheses and ‘debugging’ their own ideas.
- They often interpret their results to confirm their own ideas.

Modelling differs in intent from simulations, although in some cases the distinction is blurred. In modelling, students are able to work out for themselves how variables relate to each other, whereas in simulations they are looking at the outcomes of manipulating the models built into the program. Modelling often helps students to develop conceptual understanding and model-based reasoning starting from their existing ideas. Modelling software, which allows students to test their proposed models through virtual experiments, is particularly useful in this respect. It also helps students to recognise the role that models play in the work of scientists in making abstract ideas concrete, simplifying and clarifying complex phenomena, predicting trends and explaining mechanisms and processes. Teachers should also note the centrality of modelling in this curriculum: it is one of the reasoning tools that students must master in completing the course.

Modelling software is often used to promote conceptual changes. Students should learn to use models to analyse, predict, and explain phenomena. They should also be aware of the need to modify or extend a model or system of models and the inherent rules to account for new and increasingly complex situations. The teacher's role in these activities is to answer questions, provide help where needed, give appropriate scaffolding, monitor students' progress, and gain insights into particular difficulties.

(c) IT for learning through co-construction

The convenient access to vast amounts of information on the Internet provides a good platform for co-construction of knowledge. The opportunities to exchange views in real-time, even after school, on the Internet have promoted the building of learning communities amongst students. The Internet offers many opportunities for active learning as students can, for example:

- collaborate with peers in other schools, sharing data, reports or thoughts;
- research and deal with real data from companies or environmental campaigns;
- obtain live news or data about, say, the air pollution index or a disaster in another part of the world;
- access learning materials or journals not available in school;
- talk to scientists and ask them questions; and
- publish their work.

While the Internet has greatly increased our access to information, teachers may risk wasting lesson time on futile searches. Rather than asking students to search the Internet openly, it is useful to provide them with hints, such as key words, for searches or define a particular area as a starting point. It is also helpful for teachers to preview and bookmark sites, or make connections to useful sites in their school webpages, before lessons.

There is also some computer software (e.g. Knowledge Forum) which allows students to create a knowledge-building community in which they can share information, launch collaborative investigations and build networks of new ideas together. This enables students to contribute their own ideas in collaborative knowledge-building.

6.3.4 Community resources

Various government departments, non-government agencies and educational institutions can contribute to promoting life-wide learning in science by providing students with real-life learning experiences as well as up-to-date information and professional services.

A number of community resources are provided in Appendix 3 for teachers' reference, but the list is by no means exhaustive. Teachers are encouraged to explore further learning opportunities available in the community and use them effectively to make science learning and teaching interesting, authentic and meaningful.

In addition, parents and alumni can provide valuable support for student learning. Parents and alumni from different professions can be invited to deliver speeches or lectures to enable students to gain authentic knowledge about various disciplines and careers. They can also discuss social, moral and ethical issues related to science with students, and share their experience as a life-long learner.

6.4 Resource Management

A culture of sharing is the key to the success of knowledge management. Schools should make arrangements for:

- teachers and students to share learning and teaching resources through the Intranet or other means within the school;
- teachers to form professional development groups for face to face and electronic exchange of experience.

Integrated Science is a new curriculum designed to encourage an interdisciplinary approach to the learning of science. Its content is drawn from the well-established disciplines of

Biology, Chemistry and Physics. Teachers may look into the resources developed for the learning and teaching of the three subjects to identify materials relevant to the topics in the Integrated Science curriculum. However, the focus of concern and the breadth and depth required in Integrated Science may differ from that in the subject for which the resources have been prepared – so teachers need to use these resources flexibly, and may have to bridge the gap between student experience and what is required by these resources. Useful resources developed by the Science Education Section of the EMB can be found on the following website: http://www.edb.gov.hk/sc. Also, to assist schools in managing curriculum change, the EMB has developed a curriculum resources directory service at www.edb.gov.hk/cr. This provides a central pool of useful ready-to-use learning and teaching resources and references produced by the EMB and other parties.

Teachers of Integrated Science should work closely with teacher-librarians in managing and storing resources systematically, and providing a variety of resources of different kinds for students. The teacher-librarian, as an information specialist, is in the best position to help students to acquire the appropriate and ethical skills and attitudes in handling information.

Lastly, to assist schools in implementing the senior secondary curriculum, the EMB will continue to provide them with additional funding and allow flexibility in the use of resources to cater for their diverse needs. Schools are advised to refer to the relevant circulars issued by the EMB from time to time.

Timetable arrangement and deployment of teachers to cater for the diverse needs of students

There are four subjects – Biology, Chemistry, Physics and Science (including Mode I and Mode II) – on offer in the Science Education KLA, leading to a number of different subject combinations for students. The provision of these options serves the needs of students pursuing different pathways. Possible ways of managing school time-tabling and resources to allow students more choice are discussed below.

Implementation of Mode I – Integrated Science Curriculum

If this subject is to be taken by a class of students as a single elective subject, the normal time-tabling for elective subjects can be adopted. It is common practice in schools for teachers to be involved in teaching a course for three years. However, due to the multi-disciplinary nature of this subject, schools may consider assigning teachers with different expertise to teach this subject at different levels (S4, 5 and 6), or two teachers with different subject expertise to teach one class, so that teachers can focus more on modules with which they are familiar. This also helps share out the effort required in preparing for the new curriculum.

We encourage schools to promote partnership in the preparation of lessons, team teaching and lesson observation, so that teachers can learn from each other. It is recommended that schools reserve time for collaborative lesson planning in the time-table so that teachers can work together.

In cases where a school is offering this subject to two or more classes, it is advisable to assign teachers with different subject expertise to the different classes. With special time-tabling, it will be possible to swap classes so that teachers can concentrate on the modules they know best. After a few years, the teachers will be able to cover the teaching of the whole curriculum and be better placed to monitor the progress of the students.

The following table illustrates the different arrangements that schools may adopt, according to the resources they have and the readiness of their teachers:

Option A:	One teacher teaches one class at all three levels. If the teacher is required to teach beyond his/her own expertise, more time should be allowed for his/her professional development in knowledge updating and lesson preparation.
Option B:	Teachers with different expertise share the teaching of one class. This allows them to concentrate on preparing the modules in the areas in which they are most knowledgeable.
Option C:	Two teachers with different expertise teach two classes, with each teaching one class. These teachers should share their knowledge and experience regularly and help each other in preparing resources.
Option D:	Two teachers with different expertise teach two classes, with a special time-tabling arrangement which allows them to swap their responsibilities at various times in the year.

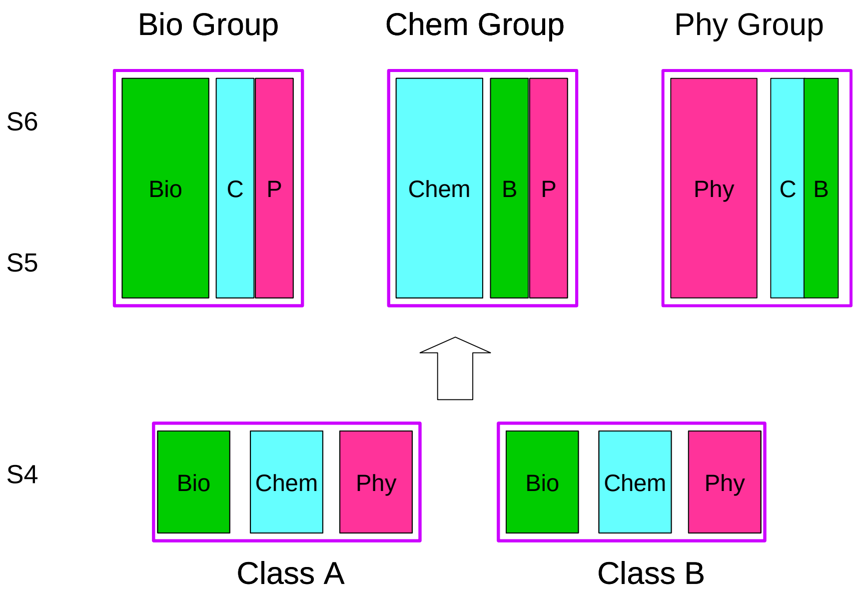
Implementation of Mode II – Combined Science Curriculum with Biology, Chemistry and Physics

The Combined Science Curriculum is designed for students taking two elective subjects in the Science Education KLA; it comprises three parts with the content selected from the Biology, Chemistry and Physics curricula. Students will have to take the two parts that are complementary to the discipline in which they specialise. Special time-tabling and staff deployment are needed for its smooth implementation in schools.

To help students build up a broad knowledge base, it is recommended that they should be offered more elective subjects in S4, and be guided to select two or three electives to focus on in S5 and S6. Students wishing to take two elective subjects in the Science Education KLA should start with all three science disciplines using the lesson time for two elective subjects in S4. That is, if four periods per cycle are allocated for one elective subject, schools may arrange three periods for each science discipline in S4. Teachers should refer to the respective Curriculum and Assessment Guides for a selection of topics suitable for inclusion in the S4 curriculum to help students build up a broad-based foundation. Schools may consider the following two arrangements in S5 and S6:

A) Flexible grouping and split class arrangement

Students from two or three different classes are arranged into three groups – namely, a Biology group, a Chemistry group and a Physics group, depending on the specialised subject they opt for. As illustrated in the diagram below, the students will have four periods per cycle for their specialised subject and two lessons per cycle for the other two complementary subjects.



An example of 2 classes taking 2 elective subjects from the Science Education KLA

To implement the split-class arrangement, three common blocks in the time-table have to be arranged for the Biology, Chemistry and Physics teachers. That is, in the four periods allocated for the 1st Block, the respective subject teachers will be teaching the groups that chose to specialise in their areas. In the 2nd and 3rd Blocks, they will give two lessons each to the groups taking the other two specialised subjects.

	Biology Teacher	**Chemistry Teacher**	**Physics Teacher**
1st Block (4 periods)	Biology (Bio Group)	Chemistry (Chem Group)	Physics (Phy Group)
2nd Block (2 periods)	Combined Science (Bio part) (Chem Group)	Combined Science (Chem part) (Phy Group)	Combined Science (Phy part) (Bio Group)
3rd Block (2 periods)	Combined Science (Bio part) (Phy Group)	Combined Science (Chem part) (Bio Group)	Combined Science (Phy part) (Chem Group)

B) Block time-table arrangement

Schools may arrange three common blocks in the time-table for three classes. The three subjects in each block will share the same time slots in the time-table. In each block, students may take any one subject from the three subjects offered in the block.

	Class A	Class B	Class C	Other Classes
Core subjects	Chin Lang	Chin Lang	Chin Lang	Chin Lang
	Eng Lang	Eng Lang	Eng Lang	Eng Lang
	Math	Math	Math	Math
	LS	LS	LS	LS
1st Block	Bio/Com Sci (Chem, Bio)/X from other KLAs			Integrated Science
2nd Block	Chem/Com Sci (Phy, Chem.)/X from other KLAs			X from other KLAs
3rd Block	Phy/Com Sci (Bio, Phy.)/X from other KLAs			X from other KLAs

In the above arrangement, X is an elective subject from the other KLAs or an ApL course. Students in Classes A, B and C are offered the following possible choices:

- Biology + 2X
- Chemistry + 2X
- Physics + 2X
- Biology + Combined Science (Phy, Chem) + X
- Chemistry + Combined Science (Bio, Phy) + X
- Physics + Combined Science (Chem, Bio) + X
- Biology + Chemistry + X
- Chemistry + Physics + X
- Biology + Physics + X
- Biology + Chemistry + Physics
- 3X (from other KLAs/ApL)

From the time-table, it is clear that two teachers of each science discipline are needed. For example, in the first common block, one Biology teacher is needed to teach four lessons of Biology and another Biology teacher is needed to teach the two lessons for the Biology part of the Combined Science.

Prior Knowledge Developed in the Science (S1-3) Curriculum

Relationship between the various modules in the Integrated Science curriculum and students' prior knowledge developed in the Science (S1-3) curriculum.

Integrated Science curriculum		**Science (S1-3)**	
Modules		**Units**	
C1	**Water for Living**	3.1 5 6.1 6.3	The basic units of living things The Wonderful Solvent – Water States of matter Particle model for the three states of matter Molecules
C2	**Balance within Our Body**	3.1 11.1 11.9 11.10 11.11 12.2 12.5	The basic units of living things Sensing the environment The brain and our senses Responses to stimuli Effects of drugs and solvents on our senses Food substances How food is digested and absorbed in our body The fate of digested food Our circulatory system
C3	**Science in a Sprint**	3.1 4.2 7.3 9.1 9.2	The basic units of living things Energy changes How does man obtain energy Forces Friction
C4	**Chemical Patterns**	6 8.3 13.2 15.5	Matter as Particles Current How to obtain metals Beyond infra-red and ultra-violet
C5	**Electrical Enlightenment**	4.4 8	Generating electricity Making Use of Electricity

C6	**Balance in Nature**	2.3 2.5 7.4 7.5 7.6 13.5 14.2	Diversity of plant and animal life Endangered species How do green plants obtain energy Gaseous exhange in animals and plants Balance of carbon dioxide and oxygen in nature Environmental problems associated with the disposal of used metals Environmental problems associated with the disposal of plastics
C7	**Radiation and Us**	15.3 15.4 15.5	Colour Beyond the visible spectrum Beyond the infra-red and ultra-violet
C8	**From Genes to Life**	3.1 3.2 3.4 12.5	The basic units of living things A new life is born Pregnancy How food is digested and absorbed in our body The fate of the digested food
E1	**Energy, Weather and Air Quality**	4.4 5.3 6.4 6.5 6.6 7.1 7.2	Generating electricity The water cycle Gas pressure Density Thermal expansion and contraction What is air made up of Burning
E2	**Keeping Ourselves Healthy**	3.1 12.1 12.8 12.9	The basic units of living things Keeping our bodies healthy How fatty food affects our circulatory system Exercise and health Need for rest
E3	**Chemistry for World Needs**	5.2 6 14	Further treatment of water Matter as Particles Materials of the Modern World

Community Resources

Organiser	Activity	Telephone Number
Agriculture, Fisheries and Conservation Department	Endangered Species Resources Centre • The Centre occupy an area of about 1,700 square feet, is situated in Room 601, 6/F, Cheung Sha Wan Government Offices, 303 Cheung Sha Wan Road, Kowloon, Hong Kong. • The Centre has some 600 specimens of about 200 endangered species on display. • Guided tours are available and advanced booking is required. (Website: http://www.afcd.gov.hk/english/conservation/con_end/con_end_pub/con_end_pub_esrc/con_end_pub_esrc.html)	2150 6974
	The Hong Kong Herbarium • The Hong Kong Herbarium is the most comprehensive herbarium in Hong Kong. There are approximately 38,000 plant specimens for examination. • By prior appointments, interested persons are welcome to visit the Herbarium and study the specimen collection and the reference books kept at the Herbarium library. Group visit up to 20 people for schools and other non-profit making organisations could also be arranged on Saturday morning. (Website: http://www.hkherbarium.net/Herbarium/index.html)	2150 6900

Organiser	Activity	Telephone Number
	Hong Kong Wetland Park • The HKWP is a millennium capital works project to promote wetland conservation, education and tourism in Hong Kong . Located at the northern part of Tin Shui Wai, the HKWP is situated at the south-western tip of the Mai Po Inner Deep Bay Ramsar Site. Over 100,000 waterbirds visit the Ramsar Site every year. • The HKWP is about 61-hectare in size. It includes the Visitor Centre of about 10,000 square metres gross floor area and 60 hectares of Wetland Reserve for wildlife. The Visitor Centre contains themed exhibition galleries on biodiversity, civilisation and conservation, as well as theatre, souvenir shop, cafe, play area, classroom and resource centre. The Wetland Reserve consists of re-created wetland habitats for waterbirds, and outdoor visitor facilities including Wetland Discovery Centre, educational walks, boardwalks and bird hides. • Education resources, like Park Experience, School Visits and Teachers workshop are available for schools. (Website: http://www.wetlandpark.com/en/index.asp)	2708 8885
Education and Manpower Bureau	• Various science related activities and competitions for students will be held each year. Schools can get the information through circulars issued by the Education and Manpower Bureau (Website: http://www.edb.gov.hk/index.aspx?nodeID=2816&langno=2)	2891 0088

Organiser	Activity	Telephone Number
Food and Environmental Hygiene Department	Health Education Exhibition and Resource Centre • It comprises a 1,100-square-metre exhibition area accommodated on two floors of a historical building which is over a hundred years old, a 400-square-metre outdoor health education garden, a resource centre holding a collection of over 6,000 items of publications, one lecture room with 75 seats and an office for the Centre's staff. (Website: http://www.fehd.gov.hk/research_education/heerc/index.html)	2377 9275
Friends of the Earth	• Friends of the Earth has been one of the major advocates of environmental education. • School Talks & Workshops on environmental issues can be provided. • Eco-resources are available for rental. (Website: http://www.foe.org.hk/welcome/geten.asp)	2528 5588
Hong Kong Observatory	• Introduces the work of the Hong Kong Observatory • Displays – instruments for weather observation and environmental radiation. • Guided tours are available for public. Visitors can see how weather forecasts are made and how technology is put to use. They will also have a chance to see some elegant historical buildings and appreciate the ecology of a mini-forest in the heart of the city. (Website: http://www.weather.gov.hk)	2926 8200

Organiser	**Activity**	**Telephone Number**
Hong Kong Science Museum	• The Hong Kong Science Museum was opened on 18 April 1991. It offers a fascinating opportunity for discovering the mystery of science. • The four-storey museum occupies a site of 12,000 square metres while its exhibition halls cover a total floor area of 6 500 square metres. • There are about 500 exhibits, 60% of which are hands-on exhibits. • Guided Tour Services for schools are available (Website: http://www.lcsd.gov.hk/CE/Museum/Science/)	2732 3232
Hong Kong Space Museum	• Hong Kong Space Museum has two thematic exhibition halls: the Hall of Space Science and the Hall of Astronomy on the ground and first floors respectively. The exhibits, predominately interactive, enable visitors to learn through a series of entertaining and educational experiences. • Teacher's Corner: Self-Learning Astronomy Course, Space Race Board Game (Website: http://www.lcsd.gov.hk/CE/Museum/Space/)	2721 0226
Hospital Authority	Health InfoWorld • The Hospital Authority launched its Health InfoWorld on 30 January 1999. It serves as a springboard to bring public, patients, and health care professionals together through health awareness programmes including talks, exhibitions, seminars, sharing sessions, etc. (Website: http://www13.ha.org.hk/healthinfoworld/index.aspx)	2300 7733

Organiser	Activity	Telephone Number
Kadoorie Farm and Botanic Garden	• Educational programme to stimulate students' appreciation of nature and to arouse their support for environmental conservation. • Through learning in nature and studying local environmental issues, students can better understand our responsibility to environmental conservation. (Website: http://www.kfbg.org.hk/)	2488 1317
LIONS Nature Education Centre	• LIONS Nature Education Centre aims at encouraging the public to experience the beauty of nature and promotes the message of conservation. • The facilities include Countryside Hall, Agriculture Hall, Fisheries Hall, Insectarium, Shell House, Dragonfly Pond, Specimen Orchard, Medicinal Herbal Garden, Interesting Plants, Arboretum, Field Corps and Mineral Corner. (Website: http://www.chungtien.com/lnec/lnec.htm)	2792 2234
Ocean Park Academy・Hong Kong	• It was established in 2004 to make use of the unique environment of the Ocean Park to help students to explore the natural world with fun. • A variety of programmes are available for students of different levels. 'Physics in Motion' is a programme designed for students to explore the beauty of mechanics by experiencing the various Ocean Park rides. Useful references can also be found in the website 'Contextual Physics in Ocean Park'. (http://www.hk-phy.org/oceanpark/index.html) • A 'Project-based learning at Ocean Park' (POP) Scheme is also developed for senior secondary school students. (Website: http://www.oceanpark.com.hk/opahk/eng/index.asp)	2552 0291

Organiser	Activity	Telephone Number
Ocean Park Conservation Foundation, Hong Kong	'Hand-in-Hand, conserve the wildlife' Award Scheme • To advocate, facilitate and participate in the conservation of wildlife animals in Asian region, including marine mammals, giant pandas, birds, reptiles and amphibians, and their habitats in Asia through research and education. • A variety of activities like 'Dolphin Encounter Boat Trip' and 'Coastal Clean-Up' are provided. (Website: http://www.opcf.org.hk/eng/index.asp)	2873 8704
World Wide Fund For Nature Hong Kong	Island House Conservation Studies Centre • The grounds of Island House cover an area of 1.75 hectares and are a mixture of formal gardens and lawns in the English style, with over 140 identified species of plants. It is an outdoor classroom for organising plant-themed environmental education activities to help students discover the 'secrets' of plants through a fun-filled learning experience. Mai Po • Tailor-made educational programmes are organised for primary and secondary students. In the tour, visitors are guided by professional interpreter to explore the gei wai, fishponds, bird hide and Education Centre etc, to appreciate the beauty of Mai Po and also learn more the importance of wetland environments. (Website: http://www.wwf.org.hk/eng/index.php)	2526 1011

Glossary

Term	Description
Applied Learning (ApL, formerly known as Career-oriented Studies)	Applied Learning is an essential component of the three-year senior secondary curriculum. ApL uses broad professional and vocational fields as the learning platform, developing students' foundation skills, thinking skills, people skills, positive values and attitudes and career-related competencies, to prepare them for further study/work as well as lifelong learning. ApL courses complement the 24 senior secondary subjects, adding variety to the senior secondary curriculum.
Assessment objectives	The outcomes of the curriculum to be assessed in the public assessments.
Biliterate and trilingual	Capable of reading and writing effectively in Standard Written Chinese, English and to use Cantonese, Putonghua and spoken English. The language education policy of Hong Kong is to enable the Hong Kong students to become biliterate (in written Chinese and English) and trilingual (in Cantonese, Putonghua and spoken English).
Co-construction	Different from the direct instruction and construction approaches to learning and teaching, the co-construction approach emphasises the class as a community of learners who contribute collectively to the creation of knowledge and the building of criteria for judging such knowledge.
Core subjects	Subjects recommended for all students to take at senior secondary level: Chinese Language, English Language, Mathematics and Liberal Studies.
Curriculum and Assessment (C&A) Guide	A guide prepared by the CDC-HKEAA Committee. It comprises curriculum aims/objectives, learning content, learning outcomes, and assessment guidelines.

Term	Description
Curriculum interface	Curriculum interface refers to the interface between the different key stages/educational stages of the school curriculum (including individual subjects), e.g. the interface between kindergarten and primary; primary and secondary; and junior secondary and senior secondary. The Hong Kong school curriculum, made up of eight key learning areas (under which specific subjects are categorised), provides a coherent learning framework to enhance students' capabilities for whole-person development through engaging them in the five essential learning experiences and helping them develop the nine generic skills as well as positive values and attitudes. Thus when students move on to senior secondary education, they will already have developed the basic knowledge and skills that the study of various subjects requires. When designing the learning and teaching content and strategies, teachers should build on the knowledge and learning experiences students have gained in the previous key stages.
Elective subjects	A total of 20 subjects in the proposed new system from which students may choose according to their interests, abilities and aptitudes.
Generic skills	Generic skills are skills, abilities and attributes which are fundamental in helping students to acquire, construct and apply knowledge. They are developed through the learning and teaching that take place in different subjects or key learning areas, and are transferable to different learning situations. Nine types of generic skills are identified in the Hong Kong school curriculum, i.e. collaboration skills, communication skills, creativity, critical thinking skills, information technology skills, numeracy skills, problem solving skills, self-management skills and study skills.
Hong Kong Diploma of Secondary Education (HKDSE)	The qualification to be awarded to students after completing the three-year senior secondary curriculum and taking the public assessment.
Internal assessment	This refers to the assessment activities that are conducted regularly in school to assess students' performance in learning. Internal assessment is an inseparable part of the learning and teaching process, and it aims to make learning more effective. With the information that internal assessment provides, teachers will be able to understand students' progress in learning, provide them with appropriate feedback and make any adjustments to the learning objectives and teaching strategies they deem necessary.

Term	Description
Key Learning Area (KLA)	Organisation of the school curriculum structured around fundamental concepts of major knowledge domains. It aims at providing a broad, balanced and coherent curriculum for all students in the essential learning experiences. The Hong Kong curriculum has eight KLAs, namely, Chinese Language Education, English Language Education, Mathematics Education, Personal, Social and Humanities Education, Science Education, Technology Education, Arts Education and Physical Education.
Knowledge construction	This refers to the process of learning in which learners are involved not only in acquiring new knowledge, but also in actively relating it to their prior knowledge and experience so as to create and form their own knowledge.
Learning community	A learning community refers to a group of people who have shared values and goals, and who work closely together to generate knowledge and create new ways of learning through active participation, collaboration and reflection. Such a learning community may involve not only students and teachers, but also parents and other parties in the community.
Learning differences	This refers to the gaps in learning that exist in the learning process. Catering for learning differences does not mean rigidly reducing the distance between the learners in terms of progress and development but making full use of their different talents as invaluable resources to facilitate learning and teaching. To cater to learners' varied needs and abilities, it is important that flexibility be built into the learning and teaching process to help them recognise their unique talents and to provide ample opportunities to encourage them to fulfil their potential and strive for achievement.
Learning outcomes	Learning outcomes refer to what learners should be able to do by the end of a particular stage of learning. Learning outcomes are developed based on the learning targets and objectives of the curriculum for the purpose of evaluating learning effectiveness. Learning outcomes also describe the levels of performance that learners should attain after completing a particular key stage of learning and serve as a tool for promoting learning and teaching.

Term	Description
Learning targets and learning objectives	• Learning targets set out broadly the knowledge/concepts, skills, values and attitudes that students need to learn and develop. • Learning objectives define specifically what students should know, value and be able to do in each strand of the subject in accordance with the broad subject targets at each key stage of schooling. They are to be used by teachers as a source list for curriculum, lesson and activity planning.
Level descriptors	A set of written descriptions that describe what the typical candidates performing a certain level is able to do in public assessments.
Other learning experiences	For whole person development of students, 'Other Learning Experiences' (OLE) is one of the three components that complement the examination subjects and Applied Learning (formerly named as Career-oriented Studies) under the senior secondary curriculum. It includes Moral and Civic Education, Aesthetics Development, Physical Development, Community Service and Career-related Experiences.
Public assessment	The associated assessment and examination system for the Hong Kong Diploma of Secondary Education.
SBA Moderation Mechanism	The mechanism adopted by HKEAA to adjust SBA marks submitted by schools to iron out possible differences across schools in marking standards and without affecting the rank order determined by the school.
School-based assessment (SBA)	Assessments administered in schools as part of the learning and teaching process, with students being assessed by their subject teachers. Marks awarded will count towards students' public assessment results.
School-based curriculum	Schools and teachers are encouraged to adapt the central curriculum to develop their school-based curriculum to help their students to achieve the subject targets and overall aims of education. Measures may include readjusting the learning targets, varying the organisation of contents, adding optional studies and adapting learning, teaching and assessment strategies. A school-based curriculum is therefore the outcome of a balance between official recommendations and the autonomy of the schools and teachers.

Term	Description
Standards-referenced Reporting	Candidates' performance in public assessment is reported in terms of levels of performance matched against a set of standards.
Student diversity	Students are individuals with varied family, social, economic and cultural backgrounds and learning experience. They have different talents, personalities, intelligence and interests. Their learning abilities, interests and styles are, therefore, diverse.
Student learning profile	It is to provide supplementary information on the secondary school leavers' participation and specialties during senior secondary years, in addition to their academic performance as reported in the Hong Kong Diploma of Secondary Education, including the assessment results for Applied Learning courses, thus giving a fuller picture of the student's whole person development.
Values & attitudes	Values constitute the foundation of the attitudes and beliefs that influence one's behaviour and way of life. They help form principles underlying human conduct and critical judgment, and are qualities that learners should develop. Some examples of values are rights and responsibilities, commitment, honesty and national identity. Closely associated with values are attitudes. The latter supports motivation and cognitive functioning, and affects one's way of reacting to events or situations. Since both values and attitudes significantly affect the way a student learns, they form an important part of the school curriculum.

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References

References for Teachers

American Association for the Advancement of Science. (1989). *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology* Washington, DC: American Association for the Advancement of Science.

American Association for the Advancement of Science. (1990). *Science for All Americans*. New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

American Association for the Advancement of Science. (2000). *Designs for Science Literacy*. New York: Oxford University Press.

American Association for the Advancement of Science. (2001). *Atlas of Science Literacy*. Washington, DC: American Association for the Advancement of Science.

Arnold, N. (2000). *Horrible Science – Deadly Diseases*. Scholastic Ltd.

Bell, B., & Cowie, B. (2001). *Formative Assessment and Science Education*. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Biggs, J. B., & Moore, P. J. (1993). *The Process of Learning*. New York: Prentice Hall.

Black, P., & Wiliam, D. (1998a). Assessment and classroom learning. *Assessment in Education*, 5 (1), 7-74.

Black, P., & Wiliam, D. (1998b). Inside the black box: raising standards through classroom assessment. *Phi Delta Kappan* 80(2), 139-148.

Board of Studies, NSW. (2000). *Stage 6 Science KLA Handbook*. Australia: Board of Studies NSW.

Bodanis, D. (2000). $E=mc^2$. Berkley Books.

Boohan, R., & Ogborn, J. (1996a). *Energy and change – Background Stories for Teachings*. Hatfield: The Association for Science Education.

Boohan, R., & Ogborn, J. (1996b). *Energy and change – Introducing a New Approach*.

Hatfield: The Association for Science Education.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposals with educational implications. *Review of Research in Education*, 24, 61-100.

Brophy, J. (1987). Synthesis of research on strategies for motivating students to learn. *Educational Leadership*, 45(2), 40-48.

Clough, M. P., & Olson, J. K. (2004). The nature of science always part of the science story. *The Science Teacher*, 71(9), 28-31.

Colburn, A. (2004). Focusing labs on the nature of science. *The Science Teacher*, 71(9), 32-35.

Cross, R. T., & Fensham, P. J. (2000). *Science and The Citizen*. Melbourne: Arena Publications.

Curriculum Corporation. (1996). *Could We? Should We?*. Curriculum Corporation.

Curriculum Development Council. (2007). *Senior Secondary Curriculum Guide*. Hong Kong: Education and Manpower Bureau.

Curriculum Development Council. (2005). *The New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong*. Hong Kong: Education and Manpower Bureau.

Curriculum Development Council. (2001). *Learning to Learn – The Way Forward*. Hong Kong: Education and Manpower Bureau.

Curriculum Development Council. (1998). *Syllabuses for Secondary Schools: Science (S1-3)*. Hong Kong: Government Printer.

Curriculum Development Council. (2002). *Science Education KLA Curriculum Guide (P1-S3)*. Hong Kong: Government Printer.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23(7), 5-12.

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's Ideas in Science*. Milton Keynes: Open University Press.

Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education*, 13, 105-122.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making Sense of Secondary Science: Research Into Children's Ideas*. London and New York: Routledge.

Drozdowska, B., Lewis, A., Oliver, R., Peploe, K., Petheram, L., Pruden, V., et al. (2002). *Ideas and Evidence in Science*. Folens Limited.

Ebenezer, J. V., & Haggerty, S. M. (1999). *Becoming A Secondary School Science Teacher*. New Jersey: Prentice-Hall, Inc.

Education and Manpower Bureau. (2000). *2000 Policy Address: Quality Education, Policy Objective for Education and Manpower Bureau*. Hong Kong: Printing Department.

Education Commission. (2000). *Education Blueprint for the 21st Century: Learning for Life, Learning through life – Reform Proposals for the Education System in Hong Kong*. Hong Kong: Printing Department.

Einstein, A. (1996). *Out of My Later Years*. Wings Books.

Enger, S. K., & Yager, R. E. (2001). *Assessing Student Understanding in Science: A Standards-based K-12 Handbook*. California: Corwin Press, Inc.

Erickson, H. L. (2002). *Concept-Based Curriculum and Instruction: Teaching Beyond the Facts*. California: Corwin Press, Inc.

Fensham, P., Gunstone, R., & White, R. (1994). *The Content of Science: A Constructivist Approach to its Teaching and Learning*. London: The Falmer Press.

Foulds, K., Mashiter, J., & Gott, R. (1990). *Investigations in Science*. Blackie & Son Ltd.

Goldsworthy, A. (2002). *AKSIS Investigations: Making an impact*. Hatfield: The Association for Science Education.

Goldsworthy, A., Watson, R., & Wood-Robinson, V. (2000a). *AKSIS Investigations: Developing Understanding*. Hatfield: The Association for Science Education.

Goldsworthy, A., Watson, R., & Wood-Robinson, V. (2000b). *AKSIS Investigations: Getting to Grips with Graphs*. Hatfield: The Association for Science Education.

Goldsworthy, A., Watson, R., & Wood-Robinson, V. (2000c). *AKSIS Investigations: Target learning*. Hatfield: The Association for Science Education.

Gott, R., & Duggan, S. (1995). *Investigative Work in the Science Curriculum*. University of Oxford.

Harlen, W. (1993). *Teaching and Learning Science*. London: Paul Chapman Publishing Ltd.

Hoagland, M., & Dodson, B. (1998). *The Ways Life Works*. Three River Press.

Hodson, D. (1998). *Teaching and Learning Science: towards a Personalized Approach*. Buckingham: Open University Press.

Hodson, D., & Hodson, J. (1998). Science education as enculturation: some implications for practice. *School Science Review*, 80(290), 17-24.

Hodson, D., & Hodson, J. (June 1998). From constructivism to social constructivism: a Vygotskian perspective on teaching and learning science. *School Science Review*, 79(289), 33-41.

Hogan, K. (1999). *Relating Students' Personal Frameworks for Science Learning to their Cognition in Collaborative Contexts*. New York: John Wiley & Sons, Inc.

Lederman, N. (1992). Students' and teachers' conceptions of the nature of science: a review of the research. *Journal of Research in Science Teaching*, 29(4), 351-359.

Lederman, N. G., & Lederman, J. S. (2004). Revising instruction to teach nature of science. *The Science Teacher*, 71(9), 36-39.

Lo M. L., Pong, W. Y. & Chik, P. M. (2005). *For Each and Everyone: Catering for Individual Differences through Learning Studies*. Hong Kong University Press.

Lorsbach, A., & K., T. (1992). Constructivism as a referent for science teaching. *NARST News*, No 30.

McComas, W. F. (1998). *The Nature of Science in Science Education: Rationales and Strategies*. Netherlands: Kluwer Academic Publishers.

McComas, W. F. (2004). Keys to teaching the nature of science. *The Science Teacher*, 71(9), 24-27.

McKinney, D., & Michalovic, M. (2004). Teaching the stories of scientists and their discoveries. *The Science Teacher*, 71(9), 46-51.

Millar, R., Leach, J., & Osborne, J. (2000). *Improving Science Education: The Contribution of Research*. Buckingham: Open University Press.

Millar, R., & Osborne, J. (1998). *Beyond 2000: Science Education for the Future.* The report of a seminar series funded by the Nuffield Foundation. London: King's College London, School of Education.

Millar, R. H. (1994). What is 'scientific method' and can it be taught? In R. Levinson (Ed.), *Teaching Science*. London: Routledge & The Open University.

Millar, R. H. (1995). Science education and public understanding of science. In R. Hull (Ed.), *ASE Science Teachers' Handbook*. London: Simon & Schuster Education.

Millar, R. H., & Driver, R. (1987). Beyond processes. *Studies in Science Education*, 14, 33-62.

Ministry of Education. (2000). *The Ontario curriculum grades 11 and 12 – Course descriptions and prerequisites* (pp. 3-94).

Ministry of Education and Training. (1999). *Science – the Ontario Curriculum, Grades 9 and 10*.

Monk, M., & Osborne, J. (2000). *Good Practice In Science Teaching*. Buckingham: Open University Press.

Narguizian, P. (2004). Understanding the nature of science through evolution. *The Science Teacher*, 71(9), 40-45.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council. (1999). *Selecting Instruction Material – A guide for K-12 Science*. National Academy Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council. (2001). *Classroom Assessment and the National Science Education Standards*. National Academy Press.

National Science Teachers Association. (1997). *Decisions based on Science*. National Science Teachers Association.

Needham, C., Hoagland, M., McPherson, K., & Dodson, B. (2000). *Intimate Strangers: Unseen Life on Earth*. SASM Press.

Nuffield Curriculum Centre and The University of York. (2007). *Twenty-first Century Science-Resources*. Oxford University Press. Website:

http://www.twentyfirstcenturyscience.org/marketing/resources.htm (accessed January 2007)

Organization for Economic Co-operation and Development. (2000). *Education at a Glance: OECD Database2000*. Paris: OECD.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What 'Ideas-about-science' should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching*, 40(7), 692-720.

Osborne, J., Driver, R., & Simon, S. (1998). Attitudes to science: issues and concerns. *School Science Review*, 79, 27-33.

Oxford Cambridge and RSA Examinations. (2007). Twenty First Century Science Suite GCSE in *Science A J630 specification*. Website: http://www.ocr.org.uk/qualifications/GCSEScience_TwentyFirstCenturyScienceSuite-for2006.html (accessed January 2007)

Pereira, L. (1996). Stepping out with the constructivists. *Australian Science Teachers Journal*, 42(2), 26-28.

Pool, M. (1995). *Beliefs and values in science education*. Buckingham: Open University Press.

Posner, G. J., Strike , K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66(2), 211-227.

Rakow, S. J. (2000). *NSTA Pathways to the Science Standards*. NSTA Press.

Ratcliffe, M., & Grace, M. (2003). *Science Education for Citizenship: Teaching Socio-Scientific Issues*. Berkshire: Open University Press.

Rudge, D. W., & Howe, E. M. (2004). Incorporating history into the science classroom. *The Science Teacher*, 71(9), 52-57.

Scott, P. (1996). Social interactions and personal meaning making in secondary science classrooms. In G. Welford, J. Osborne & P. Scott (Eds.), *Research in Science Education in Europe*. The Falmer Press.

Solomon, J. (1991a). *Exploring the Nature of Science Key Stage 3*. Hatfield: The Association for Science Education.

Solomon, J. (1991b). *Exploring the Nature of Science Key Stage 4*. Hatfield: The Association for Science Education.

Stiggins, R. (2004). New assessment beliefs for a new school mission. *Phi Delta Kappan*, 86 (1), 22-27.

Strathern, P. (1998). *The Big Idea: Bohr and Quantum Theory*. Arrow Books.

Suplee, C. (1996). *Everyday Science Explained*. National Geographic Society.

The Institute of Physics. (1997). *Physics for Sports*. Heinemann Educational Publishers.

Vygotsky, L. (1986). *Thought and Language*. Cambridge, MA: MIT Press.

Vygotsky, L. S. (1960). *The Development of Higher Mental Functions*. Moscow: Akad. Ped. Nauk. RSFSR.

Wellington, J.J. & Osborne, J. (2001). *Language and literacy in science education*. Buckingham: Open University Press.

White, R., & Gunstone, R. (1992). *Probing Understanding*. London: The Falmer Press.

Wiske, M. S. (1998). *Teaching for Understanding: Linking Research with Practice*. San Francisco: Jossey-Bass Publishers.

Yager, R. E. (1993). *The Science, Technology, Society Movement*. Washington, USA: The National Science Teachers Association.

中華人民共和國教育部 (2002) 《普通高中化學課程標準（實驗）解讀》。湖北：湖北教育出版社。

中華人民共和國教育部 (2002) 《普通高中生物課程標準（實驗）解讀》。湖北：湖北教育出版社。

中華人民共和國教育部 (2002) 《普通高中物理課程標準（實驗）解讀》。湖北：湖北教育出版社。

尼達姆、霍格蘭、麥克佛森、竇德生 (2005a) 《觀念生物學（3）：循環、網絡、複雜》。天下文化書坊。

尼達姆、霍格蘭、麥克佛森、竇德生 (2005b) 《觀念生物學（4）：共生、平衡、互利》。天下文化書坊。

朱慕菊 (2003) 《普通高中新課程方案導讀》。上海: 華東師範大學出版社。

金吾倫 (1982) 《科學發現的哲學》。水牛出版社。

威爾・杜蘭特 (2002) 《科學的『故事』》。好讀出版。

恩斯特・徐文克 (2005) 《亨利國王的鼻尖：19 個發明度量衡的故事》。商周出版。

張紅霞 (2003) 《科學究竟是甚麼》。教育科學出版社。

梁衡 (1991a) 《數理化通俗演義 上冊》。天地圖書有限公司。

梁衡 (1991b) 《數理化通俗演義 下冊》。天地圖書有限公司。

陳天機 (2004) 《大自然與文化：環境、創造和共同演化的故事》。中文大學出版社。

楊小平 (2001) 《守衛綠色 – 農藥與人類的生存》。曉園出版社有限公司。

霍格蘭、竇德生 (2002a) 《觀念生物學（1）：模式、能量、訊息》。天下文化書坊。

霍格蘭、竇德生 (2002b) 《觀念生物學（2）：機制、回饋、群集、演化》。天下文化書坊。

References for Students

Arnold, N. (2000). *Horrible Science – Deadly Diseases*. Scholastic Ltd.

Bloomfield, L. A. (2005). *How Things Work. The Physics of Everyday Life*. New York: Wiley.

Bodanis, D. (2000). *$E=mc^2$*. Berkley Books

Einstein, A. (1996). *Out of My Later Years*. Wings Books.

Hoagland, M., & Dodson, B. (1998). *The Ways Life Works*. Three River Press.

Hunt, A., & Millar, R. (2000). *AS Science for Public Understanding*. Oxford: Heinemann Educational.

Needham, C., Hoagland, M., McPherson, K., & Dodson, B. (2000). *Intimate Strangers: Unseen Life on Earth*. SASM Press.

Nuffield Curriculum Centre and The University of York. (2007). *Twenty-first Century Science-Resources*. Oxford University Press. Website: http://www.twentyfirstcenturyscience.org/marketing/resources.htm (accessed January 2007)

Ogborn, J., & Whitehouse, M. (2000). *Advancing Physics AS*. United Kingdom: Institute of Physics.

Solomon, J., & et al. (2000a). *Science Web Reader: Biology*. Cheltenham. Nelson Thornes

Solomon, J., & et al. (2000b). *Science Web Reader: Chemistry*. Cheltenham: Nelson Thornes

Solomon, J., & et al. (2001). *Science Web Reader: Physics*. Cheltenham: Nelson Thornes

Strathern, P. (1998). *The Big Idea: Bohr and Quantum Theory*. Arrow Books.

Wynn, C. M., & Wiggins, A. W. (1997). *The Five Biggest Ideas in Science*. New York: John Wiley & Sons, Inc.

尼達姆、霍格蘭、麥克佛森、竇德生 (2005a)《觀念生物學（3）：循環、網絡、複雜》。天下文化書坊。

尼達姆、霍格蘭、麥克佛森、竇德生 (2005b)《觀念生物學（4）：共生、平衡、互利》。天下文化書坊。

金吾倫 (1982)《科學發現的哲學》。水牛出版社。

威爾・杜蘭特 (2002) 《科學的『故事』》。好讀出版。

恩斯特・徐文克 (2005) 《亨利國王的鼻尖：19 個發明度量衡的故事》。商周出版。

張紅霞 (2003) 《科學究竟是甚麼》。教育科學出版社。

梁衡 (1991a) 《數理化通俗演義 下冊》。天地圖書有限公司。

梁衡 (1991b) 《數理化通俗演義 上冊》。天地圖書有限公司。

陳天機 (2004) 《大自然與文化：環境、創造和共同演化的故事》。中文大學出版社。

楊小平 (2001) 《守衛綠色 – 農藥與人類的生存》。曉園出版社有限公司。

霍格蘭、竇德生 (2002a) 《觀念生物學（1）：模式、能量、訊息》。天下文化書坊。

霍格蘭、竇德生 (2002b) 《觀念生物學（2）：機制、回饋、群集、演化》。天下文化書坊。

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