Science Education
Key Learning Area

Combined Science
Curriculum and Assessment Guide
(Secondary 4 - 6)

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

Recommended for use in schools by the Education Bureau
HKSARG
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Membership of the CDC-HKEAA Committee on Biology (Senior Secondary)		

Preamble

The Education and Manpower Bureau (EMB, now renamed Education Bureau (EDB)) 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* (2009). To gain a full understanding of the connection between education at the senior secondary level and other key stages, 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 was jointly prepared by the Curriculum Development Council (CDC) and the Hong Kong Examinations and Assessment Authority (HKEAA) in 2007. The first updating was made in January 2014 to align with the short-term recommendations made on the senior secondary curriculum and assessment resulting from the New Academic Structure (NAS) review so that students and teachers could benefit at the earliest possible instance. This updating is made to align with the medium-term recommendations of the NAS review made on curriculum and assessment. 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

[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*, and will be referred to as the *334 Report* hereafter.

from tertiary institutions, professionals from related fields/bodies, representatives from the HKEAA and the Vocational Training Council (VTC), as well as officers from the EDB. 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.

The C&A Guide is recommended by the EDB 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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Acronym

AL	Advanced Level
ApL	Applied Learning
ASL	Advanced Supplementary Level
C&A	Curriculum and Assessment
CDC	Curriculum Development Council
CE	Certificate of Education
EC	Education Commission
EDB	Education Bureau
EMB	Education and Manpower Bureau
HKALE	Hong Kong Advanced Level Examination
HKCAA	Hong Kong Council for Academic Accreditation
HKCEE	Hong Kong Certificate of Education Examination
HKDSE	Hong Kong Diploma of Secondary Education
HKEAA	Hong Kong Examinations and Assessment Authority
HKEdCity	Hong Kong Education City
HKSAR	Hong Kong Special Administrative Region
IT	Information Technology
KLA	Key Learning Area
KS1/2/3/4	Key Stage 1/2/3/4
LOF	Learning Outcomes Framework
MOI	Medium of Instruction
NOS	Nature of Science
NGO	Non-governmental Organisation
OLE	Other Learning Experiences
P1/2/3/4/5/6	Primary 1/2/3/4/5/6
PDP	Professional Development Programmes

QF	Qualifications Framework
RASIH	Review of the Academic Structure for Senior Secondary Education and Interface with Higher Education
S1/2/3/4/5/6	Secondary 1/2/3/4/5/6
SBA	School-based Assessment
SEN	Special Educational Needs
SLP	Student Learning Profile
SRR	Standards-referenced Reporting
STSE	Science, Technology, Society and Environment
TPPG	Teacher Professional Preparation Grant
VTC	Vocational Training Council

Chapter 1 Introduction

This chapter provides the background, rationale and aims of Combined 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 pathway.

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* (Education Commission, 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, and all subsequent consultation reports have echoed this. The *334 Report* 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 other 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 electives 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.

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

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 the deployment of teachers are given in Appendix 1.

1.3 Rationale

The emergence of a highly competitive and integrated economy, rapid scientific and technological innovations, and a growing knowledge base will continue to have a profound impact on our lives. In order to meet the challenges posed by these changes, Combined Science, like other science electives, provides a platform for developing scientific literacy and for building up essential scientific knowledge and skills for lifelong learning in science and technology.

Combined Science complements the study of one other specialised single science subject. This arrangement serves to provide a balanced learning experience for students across the sciences and broadens their future choices for further study and work. It also helps to cater for the diverse interests and needs of students.

The Combined Science courses attempt to make the study of the subject exciting and relevant. It is recommended that the learning of science should be introduced in real-life contexts. The adoption of such contexts and the range of learning, teaching and assessment strategies suggested are intended to appeal to students of all abilities and aspirations, and to stimulate their interest and motivation in learning. Together with other learning experiences, students are expected to be able to apply knowledge of science, to appreciate the relationship between science and other disciplines, to be aware of the Science-Technology-Society-Environment (STSE) connections through the discussion of contemporary issues, and to become responsible citizens.

More specific descriptions of the rationale of the subjects, Biology, Chemistry and Physics are described in the *C&A Guides of Biology, Chemistry and Physics*.

1.4 Curriculum Aims

The overarching aim of the Combined Science Curriculum is to provide science-related learning experiences for students to enable them to develop scientific literacy, so that they can participate actively in our rapidly changing knowledge-based society, prepare for further studies or careers in fields related to science, and become lifelong learners in science and technology.

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

- develop interest and maintain a sense of wonder and curiosity about science, and a respect for all living things and the environment;
- construct and apply knowledge of science, and appreciate the relationships between science and other disciplines;
- appreciate and understand the nature of science;
- develop skills for making scientific inquiries;
- develop the ability to think scientifically, critically and creatively, and solve problems individually and collaboratively in science-related contexts;
- understand the language of science and communicate ideas and views on science-related issues;
- develop open-mindedness, objectivity and pro-activeness;
- be aware of the social, ethical, economic, environmental and technological implications of science, and be able to make informed decisions and judgments on science-related issues; and
- develop an attitude of responsible citizenship, and a commitment to promote personal and community health.

1.5 Interface with the Junior Secondary Curriculum and Post-secondary Pathways

This curriculum builds on the *Syllabuses for Secondary Schools – Science (Secondary 1-3)* (CDC, 1998). Through studying the core parts of the junior secondary science curriculum, students should have developed a basic foundation in science. This secondary curriculum requires students to use the scientific knowledge and understanding and apply process skills acquired in their junior secondary science study.

Students who take Combined Science to complement their specialised study of one science subject (i.e. Biology, Chemistry or Physics) in senior secondary years, will acquire in-depth knowledge in a specialised science discipline and complement this with a foundation of science knowledge and skills over a wider spectrum. Students will be able to proceed to further study in post-secondary courses, or to a range of career pathways, in various fields related to science, technology, medicine or engineering. Figure 1.1 shows the continuum of learning for students studying Combined Science.

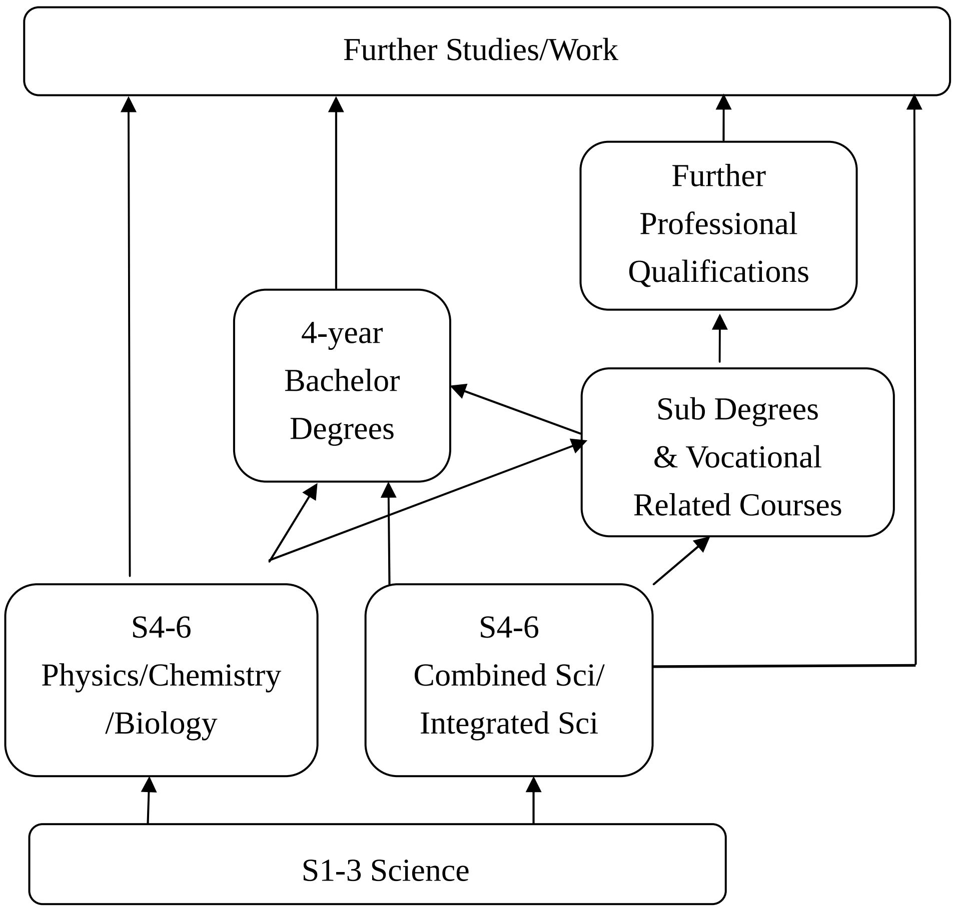

Figure 1.1 Multiple Pathways to Higher Education and the Workplace

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Chapter 2 Curriculum Framework

The curriculum framework for Combined 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 can plan their school-based curriculum and design appropriate learning, teaching and assessment activities.

2.1 Design Principles

The design of this curriculum is based on the learning goals and overarching design principles of the senior secondary curriculum as explained in Chapter 3 of the *334 Report* and Booklet 1 of the *Senior Secondary Curriculum Guide* (CDC, 2009).

(1) Prior knowledge

This curriculum builds upon the prior knowledge, skills, values and attitudes, and learning experiences expected of students in the S1-3 Science Curriculum. There is a close connection between the topics in the S1-3 Science Curriculum and the Combined Science Curriculum.

(2) Balance between breadth and depth

The Combined Science Curriculum serves as one of the elective subjects to widen the spectrum of subjects available for student choice. A balanced coverage of topics is selected to broaden the scientific understanding of students.

(3) Balance between theoretical and applied learning

Theoretical learning of the conceptual knowledge in this curriculum provides students with a solid foundation in scientific principles and concepts. Students are expected to understand the applications of scientific knowledge through studying the interrelationships of science, technology, society and the environment.

(4) Balance between essential learning and a flexible and diversified curriculum

This curriculum provides students with essential knowledge and concepts, while the choice of different combinations allows flexibility to cater for the needs and interests of students.

(5) Learning how to learn and inquiry-based learning

In this curriculum, a wide range of learning activities is suggested to help develop students' overall capacities for self-directed and lifelong learning. In addition, teachers are recommended to adopt a range of learning and teaching strategies, e.g. contextual approach, scientific investigation, problem-based learning and issue-based learning to enhance students' understanding of various contemporary issues.

(6) Progression

Students can explore their interests through the study of foundation topics in Biology, Chemistry and Physics. This will ensure smooth progression to S5 and S6 when they choose the science subject they wish to specialise in.

(7) Smoother articulation to multiple progression pathways

This curriculum enables students to pursue academic and vocational/professional education and training with articulation to a wide range of post-secondary and university studies or to the workplace.

(8) Greater coherence

There are cross-curricular elements in the curriculum to strengthen the connections with other subjects.

(9) Catering for diversity

There are differences among students in various dimensions such as interests, needs and abilities. This curriculum provides opportunity for students to choose among different combinations according to their interests and needs. It is designed to enable students to achieve the learning targets at their own pace depending on their ability.

(10) Relevance to students' life

Motivation and interest are key considerations for effective learning. This curriculum provides means to ensure that learning content and activities are relevant to students' real life, i.e. to the issues, events and substances that they encounter daily.

2.2 Learning Targets

The learning targets of the Combined Science Curriculum are categorised into three domains: knowledge and understanding, skills and processes, and values and attitudes. Through the learning embodied in the curriculum, students will achieve the relevant learning targets in various science-related contexts.

2.2.1 Knowledge and Understanding

Students are expected to:

- understand phenomena, facts and patterns, principles, concepts, laws and theories in science;
- acquire knowledge of techniques and process skills used in scientific investigation;
- apply scientific knowledge and understanding to familiar and unfamiliar situations;
- develop an understanding of developments, current issues, technological applications and social implications of science;
- appreciate the applications of science in society and in everyday life; and
- learn vocabulary, terminology and the textual conventions of science.

2.2.2 Skills and Processes

Students are expected to:

- develop scientific thinking and problem-solving skills;
- acquire an analytical mind to evaluate science-related issues critically;
- communicate scientific ideas and values in meaningful and creative ways with appropriate use of symbols, formulae, equations and conventions, as well as by verbal means;
- plan and conduct scientific investigations individually and collaboratively with appropriate instruments and methods, collect quantitative and qualitative data with accuracy, analyse and present data, draw conclusions, and evaluate evidence and procedures;
- make careful observations, ask relevant questions, identify problems and formulate hypotheses for investigation;
- realise the importance of evidence in supporting, modifying or refuting proposed scientific theories;
- acquire practical skills such as manipulating apparatus and equipment, carrying out given procedures, analysing and presenting data, drawing conclusions and evaluating experimental procedures;

- identify the pros and cons of the applications of science for informed decision-making;
- use information technology to process and present scientific information; and
- develop study skills to improve the effectiveness and efficiency of learning; as well as the abilities and habits that are essential for lifelong learning.

2.2.3 Values and Attitudes

Students are expected to:

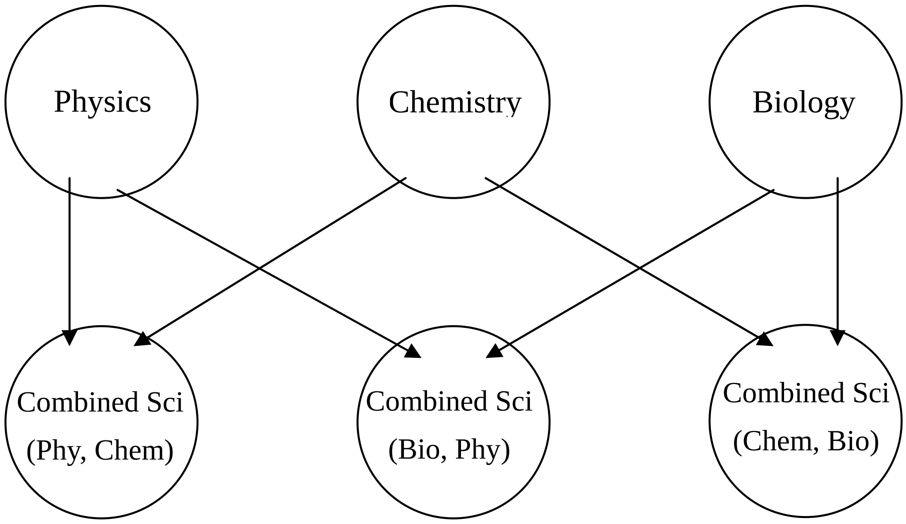
- develop positive values and attitudes such as curiosity, honesty, respect for evidence, perseverance and tolerance of uncertainty through the study of science;
- develop positive values and attitudes to health and adopt a healthy lifestyle;
- show an interest in the study of science, appreciate the wonders and complexity of Nature, and show respect for all living things and the environment;
- be aware of the dynamic nature of the body of science knowledge, appreciate the role and achievements of science and technology in understanding the world, and recognise their limitations;
- be aware of the impact of science in social, economic, industrial, environmental and technological contexts;
- be willing to communicate and make decisions on issues related to science and demonstrate an open-minded attitude towards the views of others;
- appreciate the interrelationship of science with other disciplines in providing societal and cultural values;
- appreciate the importance of working safely in a laboratory and be aware of the importance of safety for themselves and others;
- develop personal integrity through objective observation and honest recording of experimental data;
- develop a habit of self-reflection and the ability to think critically;
- recognise the importance of lifelong learning in our rapidly changing knowledge-based society; and
- recognise their responsibility for conserving, protecting and maintaining the quality of the environment for future generations.

2.3 Curriculum Structure and Organisation

2.3.1 Curriculum Structure

The curriculum consists of three parts:
Part 1: Physics
Part 2: Chemistry
Part 3: Biology

Students can choose any two parts to form a basis of study. Hence, there are three options available:



The content of the curriculum is organised into various topics. However, the concepts and principles of science are interrelated and should not be confined by any artificial boundaries between topics. The order of presentation of the topics in this chapter should be regarded as one of a range of possible teaching sequences. Teachers should adopt sequences that best suit their chosen teaching approaches. For instance, some parts of a certain topic may be covered in advance if they fit naturally into a chosen context. There are five major parts in each topic: Overview, Students Should Learn and Should Be Able to, Suggested Learning and Teaching Activities, Values and Attitudes, and Science, Technology, Society and Environment (STSE) connections.

(1) Overview

This part outlines the main theme of the topic and highlights the major concepts and important science principles to be acquired. The focus of each topic is briefly described and the interconnections between sub-topics are outlined.

(2) Students Should Learn and Should be Able to

This part lists the intentions of learning (Students Should Learn) and learning outcomes (Students Should Be Able to) to be acquired in the knowledge content domain of the curriculum. It provides a broad framework upon which learning and teaching activities can be developed. General principles and examples of learning and teaching strategies are described in Chapter 4.

(3) Suggested Learning and Teaching Activities

This part gives suggestions for some of the different skills that are expected to be acquired in the topic. Some important processes associated with the topic are also briefly described. Since most of the generic skills can be acquired through activities associated with any of the topics, there is no attempt to give direct recommendations on which topics or activities promote them. However, students need to acquire a much broader range of skills than are mentioned in the topics. Teachers should use their professional judgment to arrange activities to develop the skills listed under "Skills and Processes" in the curriculum framework. This should be done through appropriate integration with knowledge content and with due consideration to students' abilities, interests and school context. Further discussion on learning and teaching strategies is covered in Chapter 4.

(4) Values and Attitudes

This part suggests positive values and attitudes that can be promoted through discussion during the study of certain topics.

(5) STSE Connections

This part suggests some issue-based learning activities or topics related to the study topic. Students should be encouraged to develop an understanding of issues associated with the interconnections of science, technology, society and the environment. Through discussion, debate, information search and project work, students can develop their skills of communication, information handling, critical thinking and making informed judgments. Teachers are encouraged to select other issues of current public concern as themes for meaningful learning activities.

2.3.2 Time Allocation

The suggested content and time allocation[2] for each of the three subjects involved in possible Combined Science options are listed in the following tables.

Part I : Physics			**Suggested lesson time (hours)**
I	Heat	a. Temperature, heat and internal energy b. Transfer processes c. Change of state	15
II	Force and Motion	a. Position and movement b. Force and motion c. Projectile motion d. Work, energy and power e. Momentum	37
III	Wave Motion	a. Nature and properties of waves b. Light c. Sound	32
IV.	Electricity and Magnetism	a. Electrostatics b. Circuits and domestic electricity c. Electromagnetism	33
Scientific Investigations Students should conduct simple investigations in the form of experiments.			8
		Subtotal:	**125**

[2] The lesson time for Liberal Studies and each elective subject is 250 hours (or 10% of the total allocation time) for planning purpose, and schools have the flexibility to allocate lesson time at their discretion in order to enhance learning and teaching effectiveness and cater for students' needs.

"250 hours" is the planning parameter for each elective subject to meet local curriculum needs as well as requirements of international benchmarking. In view of the need to cater for schools with students of various abilities and interests, particularly the lower achievers, "270 hours" was recommended to facilitate schools' planning at the initial stage and to provide more time for teachers to attempt various teaching methods for the NSS curriculum. Based on the calculation of each elective subject taking up 10% of the total allocation time, 2500 hours is the basis for planning the 3-year senior secondary curriculum. This concurs with the reality check and feedback collected from schools in the short-term review, and a flexible range of 2400±200 hours is recommended to further cater for school and learner diversity.

As always, the amount of time spent in learning and teaching is governed by a variety of factors, including whole-school curriculum planning, learners' abilities and needs, students' prior knowledge, teaching and assessment strategies, teaching styles and the number of subjects offered. Schools should exercise professional judgement and flexibility over time allocation to achieve specific curriculum aims and objectives as well as to suit students' specific needs and the school context.

Part 2: Chemistry			**Suggested lesson time (hours)**
I	Planet Earth	a. The atmosphere b. The ocean c. Rocks and minerals	6
II	Microscopic World	a. Atomic structure b. The Periodic Table c. Metallic bonding d. Structures and properties of metals e. Ionic and covalent bond f. Structures and properties of giant ionic substances g Structures and properties of simple molecular substances h. Structures and properties of giant covalent substances i. Comparison of structures and properties of important types of substances	21
III	Metals	a. Occurrence and extraction of metals b. Reactivity of metals c. Reacting masses d. Corrosion of metals and their protection	22
IV	Acids and Bases	a. Introduction to acids and alkalis b. Indicators and pH c. Strength of acids and alkalis d. Salts and neutralisation e. Concentration of solutions f. Volumetric analysis involving acids and alkalis g. Rate of chemical reaction	27
V	Fossil Fuels and Carbon Compounds	a. Hydrocarbons from fossil fuels b. Homologous series, structural formulae and naming of carbon compounds c. Alkanes and alkenes d. Alcohols, alkanoic acids and esters e. Addition polymers and condensation polymers	19
VI	Redox Reactions, Chemical Cells and Electrolysis	a. Chemical cells in daily life b. Reactions in simple chemical cells c. Redox reactions d. Redox reactions in chemical cells e. Electrolysis	23

VII	Chemical Reactions and Energy	a. Energy changes in chemical reactions b. Standard enthalpy changes of reactions c. Hess's Law	7
Scientific Investigations Simple investigations are subsumed in the lesson time suggested for each topic.			
		Subtotal:	**125**

Part 3: Biology			**Suggested lesson time (hours)**
I	Cells and Molecules of Life	a. Molecules of life b. Cellular organisation c. Movement of substances across membrane d. Cell cycle and division e. Cellular energetics	19
II	Genetics and Evolution	a. Basic genetics b. Molecular genetics c. Biodiversity and evolution	22
III	Organisms and Environment	a. Essential life processes in plants b. Essential life processes in animals c. Reproduction, growth and development d. Coordination and response e. Homeostasis f. Ecosystems	69
IV	Health and Diseases	a. Personal health b. Diseases	5
Scientific Investigations Ten hours of the total lesson time are allocated for conducting relatively large-scale or cross-topics investigations. The time required for conducting simple investigations and practical work has already been included in the suggested lesson time for each topic.			10
		Subtotal:	**125**

<u>The detailed content of the topics and the learning outcomes of the Biology, Chemistry and Physics parts are listed in their respective sections.</u>

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Part 1: Physics

I Heat

Overview

This topic examines the concept of thermal energy and transfer processes which are crucial for the maintenance and quality of our lives. Particular attention is placed on the distinction and relationships among temperature, internal energy and energy transfer. Students are also encouraged to adopt microscopic interpretations of various important concepts in the topic of thermal physics.

Calculations involving specific heat capacity will serve to complement the theoretical aspects of heat and energy transfer. The practical importance of the high specific heat capacity of water can be illustrated with examples close to the experience of students. A study of conduction, convection and radiation provides a basis for analysing the containment of internal energy and transfer of energy related to heat. The physics involving the change of states is examined and numerical problems involving specific latent heat are used to consolidate the theoretical aspects of energy conversion.

Students should learn	Students should be able to
a. Temperature, heat and internal energy	
temperature and thermometers	• realise temperature as the degree of hotness of an object • interpret temperature as a quantity associated with the average kinetic energy due to the random motion of molecules in a system • explain the use of temperature-dependent properties in measuring temperature • define and use degree Celsius as a unit of temperature

Students should learn	Students should be able to
heat and internal energy	• realise that heat is the energy transferred as a result of the temperature difference between two objects • describe the effect of mass, temperature and state of matter on the internal energy of a system • relate internal energy to the sum of the kinetic energy of random motion and the potential energy of molecules in the system
heat capacity and specific heat capacity	• define heat capacity as $C = \frac{Q}{\Delta T}$ and specific heat capacity as $c = \frac{Q}{m\Delta T}$ • determine the specific heat capacity of a substance • discuss the practical importance of the high specific heat capacity of water • solve problems involving heat capacity and specific heat capacity
b. Transfer processes	
conduction, convection and radiation	• identify the means of energy transfer in terms of conduction, convection and radiation • interpret energy transfer by conduction in terms of molecular motion • realise the emission of infra-red radiation by hot objects • determine the factors affecting the emission and absorption of radiation
c. Change of state	
melting and freezing, boiling and condensing	• state the three states of matter • determine the melting point and boiling point
latent heat	• realise latent heat as the energy transferred during the change of state without temperature change • interpret latent heat in terms of the change of potential energy of the molecules during a change of state • define specific latent heat of fusion as $\ell_f = \frac{Q}{m}$

Students should learn	Students should be able to
	• define specific latent heat of vaporization as $\ell_v = \dfrac{Q}{m}$
	• solve problems involving latent heat
evaporation	• realise the occurrence of evaporation below boiling point • explain the cooling effect of evaporation • discuss the factors affecting rate of evaporation • explain evaporation in terms of molecular motion

Suggested Learning and Teaching Activities

Students should develop experimental skills in measuring temperature, volume, pressure and energy. The precautions essential for accurate measurements in heat experiments should be understood in terms of the concepts learned in this topic. Students should also be encouraged to suggest their own methods for improving the accuracy of these experiments, and arrangement for performing these investigations should be made, if feasible. In some of the experiments, a prior knowledge of electrical energy may be required for a solid understanding of the energy transfer processes involved.

Possible learning activities that students may engage in are suggested below for reference:

- Studying the random motion of molecules inside a smoke cell using a microscope and video camera
- Performing an experiment to show how to measure temperature using a device with temperature-dependent properties
- Calibrating a thermometer
- Reproducing fixed points on the Celsius scale
- Performing experiments to determine specific heat capacity and latent heat
- Measuring the specific latent heat of fusion of water (e.g. using a domestic electric boiler, heating an ice-water mixture in a composite container, or using ice calorimeter)
- Performing experiments to study the cooling curve of a substance and determine its melting point
- Determining factors affecting the rate of evaporation
- Feeling the sensation of coldness by touching a few substances in the kitchen and clarifying some misconceptions that may arise from their daily experience

- Studying conduction, convection, radiation, the greenhouse effect and heat capacity by designing and constructing a solar cooker
- Challenging their preconceived ideas on energy transfer through appropriate competitions (e.g. attaining a temperature closest to 4^{o}C by mixing a soft drink with ice)
- Using dimension analysis to check the results of mathematical solutions
- Reading articles on heat stroke and discussing heat stroke precautions and care

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to be aware of the proper use of heat-related domestic appliances as this helps to reduce the cost of electricity and contributes to the worthwhile cause of saving energy
- to be aware of the large amount of energy associated with the transfer of heat and to develop good habits in using air-conditioning in summer and heating in winter
- to develop an interest in using alternative environmentally friendly energy sources such as solar and geothermal energy
- to be aware of the importance of home safety in relation to the use of radiation heaters and to be committed to safe practices in daily life

STSE Connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the importance of greenhouses in agriculture and the environmental issues of the "greenhouse effect"
- debates on the gradual rise in global temperature due to human activities, the associated potential global hazards due to the melting of the polar ice caps and the effects on the world's agricultural production
- projects, such as the "Design of Solar Cooker", to develop investigation skills as well as foster the concept of using alternative environmentally friendly energy sources

II Force and Motion

Overview

Motion is a common phenomenon in our daily experience. It is an important element in physics where students learn to describe how objects move and investigate why objects move in the way that they do. In this topic, the fundamentals of mechanics in kinematics and dynamics are introduced, and the foundation for describing motion with physics terminology is laid. Various types of graphical representation of motion are studied. Students learn how to analyse different forms of motion and solve simple problems relating to uniformly accelerated motion. They also learn about motion in one or two dimensions and rules governing the motion of objects on Earth.

The concept of inertia and its relation to Newton's First Law of motion are covered. Simple addition and resolution of forces are used to illustrate the vector properties of forces. Free-body diagrams are used to work out the net force acting on a body. Newton's Second Law of motion, which relates the acceleration of an object to the net force, is examined. The concepts of mass, weight and gravitational force are introduced. Newton's Third Law of motion is related to the nature of forces. The study of motion is extended to projectile motion which leads to an investigation of gravitation.

Work is a process of energy transfer. The concepts of mechanical work done and energy transfer are examined and used in the derivation of kinetic energy and gravitational potential energy. Conservation of energy in a closed system is a fundamental concept in physics. The treatment of energy conversion is used to illustrate the law of conservation of energy, and the concept of power is also introduced. Students learn how to compute quantities such as momentum and energy in examples involving collisions. The relationship among the change in the momentum of a body, impact time and impact force is emphasised.

Students should learn	Students should be able to
a. Position and movement	
position, distance and displacement	• describe the change of position of objects in terms of distance and displacement • present information on displacement-time graphs for moving objects
scalars and vectors	• distinguish between scalar and vector quantities • use scalars and vectors to represent physical quantities
speed and velocity	• define average speed as the distance travelled in a given period of time and average velocity as the displacement changed in a period of time • distinguish between instantaneous and average speed/velocity • describe the motion of objects in terms of speed and velocity • present information on velocity-time graphs for moving objects • use displacement-time and velocity-time graphs to determine the displacement and velocity of objects
uniform motion	• interpret the uniform motion of objects using algebraic and graphical methods • solve problems involving displacement, time and velocity
acceleration	• define acceleration as the rate of change of velocity • use velocity-time graphs to determine the acceleration of objects in uniformly accelerated motion • present information on acceleration-time graphs for moving objects
equations of uniformly accelerated motion	• derive equations of uniformly accelerated motion $v = u + at$ $s = \frac{1}{2}(u + v)t$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ • solve problems involving objects in uniformly accelerated motion

Students should learn	Students should be able to
vertical motion under gravity	• examine the motion of free-falling objects experimentally and estimate the acceleration due to gravity • present graphically information on vertical motions under gravity • apply equations of uniformly accelerated motion to solve problems involving objects in vertical motion • describe the effect of air resistance on the motion of objects falling under gravity
b. Force and motion	
Newton's First Law of motion	• describe the meaning of inertia and its relationship to mass • state Newton's First Law of motion and use it to explain situations in which objects are at rest or in uniform motion • understand friction as a force opposing motion/tendency of motion
addition and resolution of forces	• find the vector sum of coplanar forces graphically and algebraically • resolve a force graphically and algebraically into components along two mutually perpendicular directions
Newton's Second Law of motion	• describe the effect of a net force on the speed and/or direction of motion of an object • state Newton's Second Law of motion and verify $F=ma$ experimentally • use newton as a unit of force • use free-body diagrams to show the forces acting on objects • determine the net force acting on object(s) • apply Newton's Second Law of motion to solve problems involving motion in one dimension
Newton's Third Law of motion	• realise forces acting in pairs • state Newton's Third Law of motion and identify action and reaction pair of forces
mass and weight	• distinguish between mass and weight • realise the relationship between mass and weight

Students should learn	Students should be able to
c. Projectile motion	• describe the shape of the path taken by a projectile launched at an angle of projection • understand the independence of horizontal and vertical motions • solve problems involving projectile motion
d. Work, energy and power	
mechanical work	• interpret mechanical work as a way of energy transfer • define mechanical work done $W = Fs\cos\theta$ • solve problems involving mechanical work
gravitational potential energy (P.E.)	• state that gravitational potential energy is the energy possessed by an object due to its position under gravity • derive $P.E. = mgh$ • solve problems involving gravitational potential energy
kinetic energy (K.E.)	• state that kinetic energy is the energy possessed by an object due to its motion • derive $K.E. = \frac{1}{2}mv^2$ • solve problems involving kinetic energy
law of conservation of energy in a closed system	• state the law of conservation of energy • discuss the inter-conversion of P.E. and K.E. with consideration of energy loss • solve problems involving conservation of energy
power	• define power as the rate of energy transfer • apply $P = \frac{W}{t}$ to solve problems
e. Momentum	
linear momentum	• realise momentum as a quantity of motion of an object and define momentum $p = mv$
change in momentum and net force	• understand that a net force acting on an object for a period of time results a change in momentum • interpret force as the rate of change of momentum (Newton's Second Law of motion)

Students should learn	Students should be able to
law of conservation of momentum	• state the law of conservation of momentum and relate it to Newton's Third Law of motion • distinguish between elastic and inelastic collisions • solve problems involving momentum in one dimension only

Suggested Learning and Teaching Activities

Students should develop experimental skills in measuring time and in recording the positions, velocities and accelerations of objects using various types of measuring instruments such as stop watches and data logging sensors. Skills in measuring masses, weights and forces are also required. Data-handling skills such as converting data of displacement and time into information on velocity or acceleration are important. Students may be encouraged to carry out project-type investigations on the motion of vehicles. Considerable emphasis is placed on the importance of graphical representations of physical phenomena in this topic. Students should learn how to plot graphs with a suitable choice of scale, display experimental results in graphical forms and interpret, analyse and draw conclusions from graphical information. In particular, they should learn to interpret the physical significances of slopes, intercepts and areas in certain graphs. Students should be able to plan and interpret information from different types of data source. Most experiments and investigations will produce a set of results which may readily be compared with data in textbooks and handbooks.

Possible learning activities that students may engage in are suggested below for reference:

- Performing experiments on motion and forces (e.g. using ticker-tape timers, multi-flash photography, video motion analysis and data loggers) and a graphical analysis of the results
  - Using light gates or motion sensors to measure the speed and acceleration of a moving object
  - Inferring the relationships among acceleration, velocity, displacement and time from a graphical analysis of empirical data for uniformly accelerated motion
  - Using light gates or motion sensors to measure the acceleration due to gravity
  - Using light gates or motion sensors to determine the factors affecting acceleration
  - Using force and motion sensors to determine the relationship among force, mass and acceleration
  - Using multi-flash photography or a video camera to analyse projectile motion

- Performing experiments on energy and momentum (e.g. colliding dynamic carts, gliders on air tracks, pucks on air tables, rolling a ball-bearing down an inclined plane, dropping a mass attached to a spring)
  - Using light gates or motion sensors to measure the change of momentum during a collision
  - Using light gates or motion sensors and air track to investigate the principle of conservation of linear momentum
  - Using force sensors to measure the impulse during collision
- Performing experiments to show the independence of horizontal and vertical motions under the influence of gravity
- Performing experiments to investigate the relationships among mechanical energy, work and power
- Determining the output power of an electric motor by measuring the rate of energy transfer
- Estimating the work required for various tasks, such as lifting a book, stretching a spring and climbing Lantau Peak
- Estimating the K.E. of various moving objects such as a speeding car, a sprinter and an air molecule
- Investigating the application of conservation principles in designing energy transfer devices
- Evaluating the design of energy transfer devices, such as household appliances, lifts, escalators and bicycles
- Using free-body diagrams in organising and presenting the solutions of dynamic problems
- Tackling problems that, even if a mathematical treatment is involved, have a direct relevance to their experience (e.g. sport, transport and skating) in everyday life and exploring solutions of problems related to these experiences
- Using dimension analysis to check the results of mathematical solutions
- Challenging their preconceived ideas on motion and force by posing appropriate thought-provoking questions (e.g. “zero” acceleration at the maximum height)
- Increasing their awareness of the power and elegance of the conservation laws by contrasting such solutions with those involving the application of Newton’s Second Law of motion
- Investigating motion in a plane using simulations or modelling (http://modellus.co/index.php/en)
- Using the Ocean Park Hong Kong as a large laboratory to investigate laws of motion and develop numerous concepts in mechanics from a variety of experiences at the park (http://www.hk-phy.org/oceanpark/index.html)

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to be aware of the importance of car safety and be committed to safe practices in their daily life
- to be aware of the potential danger of falling objects from high-rise buildings and to adopt a cautious attitude in matters concerning public safety
- to be aware of the environmental implications of different modes of transport and to make an effort to reduce energy consumption in daily life
- to accept uncertainty in the description and explanation of motions in the physical world
- to be open-minded in evaluating potential applications of principles in mechanics to new technology
- to appreciate the efforts made by scientists to find alternative environmentally friendly energy sources
- to appreciate that the advances in important scientific theories (such as Newton's laws of motion) can ultimately have a huge impact on technology and society
- to appreciate the contributions of Galileo and Newton that revolutionised the scientific thinking of their time
- to appreciate the roles of science and technology in the exploration of outer-space and the efforts of humankind in the quest to understand nature

STSE Connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the effects of energy use on the environment
- the reduction of pollutants and energy consumption by restricting the use of private cars in order to protect the environment
- penalising drivers and passengers who do not wear seatbelts and raising public awareness of car safety with scientific rationales
- how the danger of speeding and its relation to the chances of serious injury or death in car accidents can be related to the concepts of momentum and energy
- the use of principles in mechanics in traffic accident investigations

- modern transportation: the dilemma in choosing between speed and safety; and between convenience and environmental protection
- evaluating the technological design of modern transport (e.g. airbags in cars, tread patterns on car tyres, hybrid vehicles, magnetically levitated trains)
- the use of technological devices including terrestrial and space vehicles (e.g. Shenzhou spacecraft)
- enhancement of recreational activities and sports equipment
- the ethical issue of dropping objects from high-rise buildings and its potential danger as the principles of physics suggest
- careers that require an understanding and application of kinematics and dynamics

III Wave Motion

Overview

This topic examines the basic nature and properties of waves. Light and sound, in particular, are also studied in detail. Students are familiar with examples of energy being transmitted from one place to another, together with the transfer of matter. In this topic, the concept of waves as a means of transmitting energy without transferring matter is emphasised. The foundations for describing wave motion with physics terminology are laid. Students learn the graphical representations of travelling waves. The basic properties and characteristics displayed by waves are examined; reflection, refraction, diffraction and interference are studied, using simple wavefront diagrams.

Students acquire specific knowledge about light in two important aspects. The characteristics of light as a part of the electromagnetic spectrum are studied. Also, the linear propagation of light in the absence of significant diffraction and interference effects is used to explain image formation in the domain of geometrical optics. The formation of real and virtual images using mirrors and lenses is studied with construction rules for light rays.

Sound as an example of longitudinal waves is examined and its general properties are compared with those of light waves. Students also learn about ultrasound. The general descriptions of musical notes are related to the terminology of waves. The effects of noise pollution and the importance of acoustic protection are also studied.

Students should learn	Students should be able to
a. Nature and properties of waves	
nature of waves	• interpret wave motion in terms of oscillation • realise waves as transmitting energy without transferring matter

Students should learn	Students should be able to
wave motion and propagation	• distinguish between transverse and longitudinal waves • describe wave motion in terms of waveform, crest, trough, compression, rarefaction, wavefront, phase, displacement, amplitude, period, frequency, wavelength and wave speed • present information on displacement-time and displacement-distance graphs for travelling waves • determine factors affecting the speed of propagation of waves along stretched strings or springs • apply $f = \frac{1}{T}$ and $v = f\lambda$ to solve problems
reflection and refraction	• realise the reflection of waves at a plane barrier/reflector/surface • realise the refraction of waves across a plane boundary • examine the change in wave speeds during refraction and define refractive index in terms of wave speeds • draw wavefront diagrams to show reflection and refraction
diffraction and interference	• describe the diffraction of waves through a narrow gap and around a corner • examine the effect of the width of slit on the degree of diffraction • describe the superposition of two pulses • realise the interference of waves • distinguish between constructive and destructive interferences • examine the interference of waves from two coherent sources • determine the conditions for constructive and destructive interferences in terms of path difference • draw wavefront diagrams to show diffraction and interference
b. Light	
light in electromagnetic spectrum	• state that the speed of light and electromagnetic waves in a vacuum is 3.0×10^8 ms^{-1} • state the range of wavelengths for visible light • state the relative positions of visible light and other parts of the electromagnetic spectrum

Students should learn	Students should be able to
reflection of light	• state the laws of reflection • construct images formed by a plane mirror graphically
refraction of light	• examine the laws of refraction • sketch the path of a ray refracted at a boundary • realise $n = \frac{\sin i}{\sin r}$ as the refractive index of a medium • solve problems involving refraction at a boundary
total internal reflection	• examine the conditions for total internal reflection • solve problems involving total internal reflection at a boundary
formation of images by lenses	• construct images formed by converging and diverging lenses graphically • distinguish between real and virtual images
wave nature of light	• point out light as an example of transverse wave • realise diffraction and interference as evidences for the wave nature of light • examine the interference patterns in the Young's double slit experiment • examine the interference patterns in the plane transmission grating

c. Sound

wave nature of sound	• realise sound as an example of longitudinal waves • realise that sound can exhibit reflection, refraction, diffraction and interference • realise the need for a medium for sound transmission • compare the general properties of sound waves and those of light waves
audible frequency range	• determine the audible frequency range • examine the existence of ultrasound beyond the audible frequency range

Students should learn	Students should be able to
musical notes	• compare musical notes using pitch, loudness and quality • relate frequency and amplitude with the pitch and loudness of a note respectively
noise	• represent sound intensity level using the unit decibel • discuss the effects of noise pollution and the importance of acoustic protection

Suggested Learning and Teaching Activities

Students should develop experimental skills in the study of vibration and waves through various physical models. They need to develop the skills for interpreting indirect measurements and demonstrations of wave motion through the displays on the CRO or the computer. They should appreciate that scientific evidence is obtained through indirect measurement coupled with logical deduction. They should also be aware that various theoretical models are used in the study of physics – for example, the ray model is used in geometrical optics for image formation and the wave model of light is used to explain phenomena such as diffraction and interference. Through the study of the physics of musical notes, students understand that most everyday experiences can be explained using scientific concepts.

Possible learning activities that students may engage in are suggested below for reference:

- Investigating the properties of waves generated in springs and ripple tanks
- Investigating factors affecting the speed of transverse progressive waves along a slinky spring
- Determining the speed of a water wave in a ripple tank or a wave pulse travelling along a stretched spring or string
- Demonstrating the superposition of transverse waves on a slinky spring
- Using CRO waveform demonstrations to show the superposition of waves
- Drawing the resultant wave when two waves interfere by using the principle of superposition
- Estimating the wavelength of microwaves by using double slit
- Demonstrating interference patterns in soap film
- Determining the effects of wavelength, slit separation or screen distance on an interference pattern in an experiment by using double slit

- Measuring the focal lengths of lenses
- Locating real and virtual images in lenses by using ray boxes and ray tracing
- Using ray diagrams to predict the nature and position of an image in an optical device
- Searching for information on the development of physics of light
- Discussing some everyday uses and effects of electromagnetic radiation
- Using computer simulations to observe and investigate the properties of waves
- Investigating the relationship between the frequency and wavelength of a sound wave
- Carrying out an experiment to verify Snell's law
- Determining the refractive index of glass or perspex
- Determining the conditions for total internal reflection to occur
- Identifying the differences between sounds in terms of loudness, pitch and quality
- Using dimension analysis to check the results of mathematical solutions

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to appreciate the need to make more use of some environmental friendly energy sources such as solar and tidal-wave energy
- to be aware that science has its limitations and cannot always provide clear-cut solutions; the advancement of science also requires perseverance, openness and scepticism, as demonstrated in the different interpretations on the nature of light in the history of physics over the past centuries
- to appreciate that the advancement of important scientific theories (such as those related to the study of light) is the fruit of the hard work of generations of scientists who devoted themselves to scientific investigations by applying their intelligence, knowledge and skills
- to be aware of the potential health hazards of a prolonged exposure to extreme noise and to make an effort to reduce noise-related disturbances to neighbours
- to be aware of the importance of the proper use of microwave ovens and to be committed to safe practices in daily life

STSE Connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- controversial issues about the effects of microwave radiation on the health of the general public through the use of mobile phones
- the biological effects of increased ultra-violet radiation from the Sun on the human body as a result of the depletion of the atmospheric ozone layer by artificial pollutants
- the problem of noise pollution in the local context
- the impact on society of the scientific discovery of electromagnetic waves and the technological advances in the area of telecommunications
- how major breakthroughs in scientific and technological development that eventually affect society are associated with new understanding of fundamental physics as illustrated by the study of light in the history of science
- how technological advances can provide an impetus for scientific investigations as demonstrated in the invention and development of the microscope, telescope and X-ray diffraction, with these scientific investigations in turn shedding light on our own origin and the position of humankind in the universe

IV Electricity and Magnetism

Overview

This topic examines the basic principles of electricity and magnetism. The abstract concept of an electric field is introduced through its relationship with the electrostatic force. The inter-relationships among voltage, current, resistance, charge, energy and power are examined and the foundation for basic circuitry is laid. As electricity is the main energy source in homes and electrical appliances have become an integral part of daily life, the practical use of electricity in households is studied. Particular attention is paid to the safety aspects of domestic electricity.

The concept of magnetic field is applied to the study of electromagnetism. The magnetic effects of electric current and some simple magnetic field patterns are studied. Students also learn the factors that affect the strength of an electromagnet. A magnetic force is produced when a current-carrying conductor is placed in a magnetic field. An electric motor requires the supply of electric current to the coil in a magnetic field to produce a turning force causing it to rotate.

The general principles of electromagnetic induction are introduced. Electrical energy can be generated when there is relative motion between a conductor and a magnetic field. Generators reverse the process in motors to convert mechanical energy into electrical energy. The operation of simple d.c. and a.c. generators are studied. Students learn how a.c. voltages can be stepped up or down with transformers. The system by which electrical energy is transmitted over great distances to our homes is also studied.

Students should learn	Students should be able to
a. Electrostatics	
electric charges	• examine the evidence for two kinds of charges in nature • realise the attraction and repulsion between charges • interpret charging in terms of electron transfer
electric field	• describe the electric field around a point charge and between parallel charged plates • represent an electric field using field lines

Students should learn	Students should be able to
b. Circuits and domestic electricity	
electric current	• define electric current as the rate of flow of electric charges • state the convention for the direction of electric current
electrical energy and electromotive force	• describe the energy transformations in electric circuits • define the potential difference (p.d.) between two points in a circuit as the electric potential energy converted to other forms per unit charge passing between the points outside the source • define the electromotive force (e.m.f.) of a source as the energy imparted by the source per unit charge passing through it
resistance	• define resistance $R = \frac{V}{I}$ • describe the variation of current with applied p.d. in metal wires, electrolytes, filament lamps and diodes • realise Ohm's law as a special case of resistance behaviour • determine the factors affecting the resistance of a wire and define its resistivity $\rho = \frac{RA}{l}$ • describe the effect of temperature on resistance of metals and semiconductors
series and parallel circuits	• compare series and parallel circuits in terms of p.d. across the components of each circuit and the current through them • derive the resistance combinations in series and parallel $R = R_1 + R_2 + \ldots..$ for resistors connected in series $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots..$ for resistors connected in parallel
simple circuits	• measure I, V and R in simple circuits • assign the electrical potential of any earthed points as zero • compare the e.m.f. of a source and the terminal voltage across the source experimentally and relate the difference to the internal resistance of the source

Students should learn	Students should be able to
	• explain the effects of resistance of ammeters and voltmeters on measurements • solve problems involving simple circuits
electrical power	• examine the heating effect when a current passes through a conductor • apply $P = VI$ to solve problems
domestic electricity	• determine the power rating of electrical appliances • use kilowatt-hour (kW h) as a unit of electrical energy • calculate the costs of running various electrical appliances • understand household wiring and discuss safety aspects of domestic electricity • determine the operating current for electrical appliances • discuss the choice of power cables and fuses for electrical appliances based on the power rating
c. Electromagnetism	
magnetic force and magnetic field	• realise the attraction and repulsion between magnetic poles • examine the magnetic field in the region around a magnet • describe the behaviour of a compass in a magnetic field • represent magnetic field using field lines
magnetic effect of electric current	• realise the existence of a magnetic field due to moving charges or electric currents • examine the magnetic field patterns associated with currents through a long straight wire, a circular coil and a long solenoid • examine the factors affecting the strength of an electromagnet
current-carrying conductor in magnetic field	• examine the existence of a force on a current-carrying conductor in a magnetic field and determine the relative directions of force, field and current • determine the factors affecting the force on a straight current-carrying wire in a magnetic field • describe the structure of a simple d.c. motor and how it works

Students should learn	Students should be able to
electromagnetic induction	• examine induced e.m.f. resulting from a moving conductor in a steady magnetic field or a stationary conductor in a changing magnetic field • apply Lenz's law to determine the direction of induced e.m.f./current • describe the structures of simple d.c. and a.c. generators and how they work • discuss the occurrence and practical uses of eddy currents
transformer	• describe the structure of a simple transformer and how it works • relate the voltage ratio to turn ratio by $\frac{V_P}{V_S}=\frac{N_P}{N_S}$ and apply it to solve problems • examine methods for improving the efficiency of a transformer
high voltage transmission of electrical energy	• discuss the advantages of transmission of electrical energy with a.c. at high voltages • describe various stages of stepping up and down of the voltage in a grid system for power transmission

Suggested Learning and Teaching Activities

Students should develop experimental skills in connecting up circuits. They are required to perform electrical measurements using various types of equipments, such as ammeters, voltmeters, multi-meters, joulemeter, CRO and data logging sensors. Students should acquire the skills in performing experiments to study, demonstrate and explore concepts of physics, such as electric fields, magnetic fields and electromagnetic induction. Students can gain practical experience related to design and engineering in building physical models, such as electric motors and generators. It should, however, be noted that all experiments involving the mains power supply and EHT supply must be carefully planned to avoid the possibility of an electric shock. Handling apparatus properly and safely is a very basic practical skill of great importance.

Possible learning activities that students may engage in are suggested below for reference:

- Showing the nature of attraction and repulsion using simple electrostatic generation and testing equipment
- Investigating the nature of the electric field surrounding charges and between parallel plates
- Measuring current, e.m.f., and potential difference around the circuit by using appropriate meters and calculating the resistance of any unknown resistors
- Verifying Ohm's law by finding the relationship between p.d. across a resistor and current passing through it
- Determining factors affecting the resistance of a resistor
- Comparing the changing resistance of ohmic devices, non-ohmic devices and semiconductors
- Designing and constructing an electric circuit to perform a simple function
- Analysing real or simulated circuits to identify faults and suggesting appropriate changes
- Comparing the efficiency of various electrical devices and suggesting ways of improving efficiency
- Performing demonstrations to show the relative directions of motion, force and field in electromagnetic devices
- Disassembling loudspeakers to determine the functions of individual components
- Constructing electric motor kits and generator kits
- Measuring the transformation of voltages under step-up or step-down transformers
- Planning and selecting appropriate equipment or resources to demonstrate the generation of an alternating current
- Using dimension analysis to check the results of mathematical solutions
- Identifying hazardous situations and safety precautions in everyday uses of electrical appliances
- Investigating the need for and the functioning of circuit breakers in household circuits
- Reading articles on the possible hazardous effects on residents living near high voltage transmission cables
- Searching for information on the uses of resistors in common appliances (e.g. volume control, light dimmer switch)

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to appreciate that the application of scientific knowledge can produce useful practical products and transform the daily life of human beings as illustrated in the numerous inventions related to electricity
- to be aware of the importance of technological utilities such as the use of electricity, to modern society and the effects on modern life if these utilities are not available for whatever reason
- to be aware of the need to save electrical energy for reasons of economy as well as environmental protection
- to be committed to the wise use of natural resources and to develop a sense of shared responsibility for sustainable development of humankind
- to be aware of the danger of electric shocks and the fire risk associated with improper use of electricity, and develop good habits in using domestic electricity

STSE Connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the effects on health of living near high-power transmission cables
- the potential hazards of the mains supply versus the convenience of "plug-in" energy and automation it offers to society
- the environmental implications and recent developments of electric vehicles as an alternative to the traditional fossil-fuel vehicles; and the role of the government on such issues
- the views of some environmentalists on the necessity to return to a more primitive or natural lifestyle with minimum reliance on technology

Part 2: Chemistry

I Planet Earth

Overview

The natural world is made up of chemicals which can be obtained from the earth's crust, the sea and the atmosphere. The purpose of this topic is to provide opportunities for students to appreciate that we are living in a world of chemicals and that chemistry is a highly relevant and important area of learning. Another purpose of this topic is to enable students to recognise that the study of chemistry includes the investigation of possible methods to isolate useful materials in our environment and to analyse them. Students who have completed this topic are expected to have a better understanding of scientific investigation and chemistry concepts learned in the junior science curriculum.

Students should know the terms "element", "compound" and "mixture", "physical change" and "chemical change", "physical property" and "chemical property", "solvent", "solute" and "saturated solution". They should also be able to use word equations to represent chemical changes, to suggest appropriate methods for the separation of mixtures, and to undertake tests for chemical species.

Students should learn	Students should be able to
a. The atmosphere	
• composition of air • separation of oxygen and nitrogen from liquid air by fractional distillation • test for oxygen	• describe the processes involved in fractional distillation of liquid air, and understand the concepts and procedures involved • demonstrate how to carry out a test for oxygen

Students should learn	Students should be able to
b. The ocean	
• composition of sea water • extraction of common salt and isolation of pure water from sea water • tests to show the presence of sodium and chloride in a sample of common salt • test for the presence of water in a sample • electrolysis of sea water and uses of the products	• describe various kinds of minerals in the sea • demonstrate how to extract common salt and isolate pure water from sea water • describe the processes involved in evaporation, distillation, crystallisation and filtration as different kinds of physical separation methods and understand the concepts and procedures involved • evaluate the appropriateness of using evaporation, distillation, crystallisation and filtration for different physical separation situations • demonstrate how to carry out the flame test, test for chloride and test for water
c. Rocks and minerals	
• rocks as a source of minerals • isolation of useful materials from minerals as exemplified by the extraction of metals from their ores • limestone, chalk and marble as different forms of calcium carbonate • erosion processes as exemplified by the action of heat, water and acids on calcium carbonate • thermal decomposition of calcium carbonate and test for carbon dioxide • tests to show the presence of calcium and carbonate in a sample of limestone/chalk/marble	• describe the methods for the extraction of metals from their ores, such as the physical method, heating alone and heating with carbon • describe different forms of calcium carbonate in nature • understand that chemicals may change through the action of heat, water and acids • use word equations to describe chemical changes • demonstrate how to carry out tests for carbon dioxide and calcium

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for information on issues related to the atmosphere, such as air pollution and the applications of the products obtained from fractional distillation of liquid air.
- using an appropriate method to test for oxygen and carbon dioxide.
- performing experiments and evaluating methods of physical separation including evaporation, distillation, crystallisation and filtration.
- using appropriate apparatus and techniques to carry out the flame test and test for chloride.
- performing a test to show the presence of water in a given sample.
- doing problem-solving exercises on separating mixtures (e.g. a mixture of salt, sugar and sand, and a mixture of sand, water and oil).
- extracting silver from silver oxide.
- investigating the actions of heat, water and acids on calcium carbonate.
- designing and performing chemical tests for calcium carbonate.
- participating in decision-making exercises or discussions on issues related to conservation of natural resources.
- describing chemical changes using word equations.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to value the need for the safe handling and disposal of chemicals.
- to appreciate that the earth is the source of a variety of materials useful to human beings.
- to show concern over the limited reserve of natural resources.
- to show an interest in chemistry and curiosity about it.
- to appreciate the contribution of chemists to the separation and identification of chemical species.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Oxygen extracted from air can be used for medicinal purposes.
- Methods involving chemical reactions are used to purify drinking water for travellers to districts without a clean and safe water supply.
- Desalination is an alternative means of providing fresh water to the Hong Kong people rather than importing water from the Guangdong province.
- Mining and extraction of chemicals from the earth should be regulated to conserve the environment.
- Products obtained by the electrolysis of sea water are beneficial to our society.

II Microscopic World

Overview

The study of chemistry involves the linkage between phenomena in the macroscopic world and the interaction of atoms, molecules and ions in the microscopic world. Through studying of the structures of atoms, molecules and ions, and the bonding in elements and compounds, students will acquire knowledge of some basic chemical principles. These can serve to further illustrate the macroscopic level of chemistry, such as patterns of changes, observations in various chemical reactions, the rates of reactions and chemical equilibria. In addition, students should be able to perform calculations related to chemical formulae, which are the basis of mole calculations to be studied in later topics.

Students should also be able to appreciate the interrelation between bonding, structures and properties of substances by learning the properties of metals, giant ionic substances, simple molecular substances and giant covalent substances. With the knowledge of various structures, students should be able to differentiate the properties of substances with different structures, and to appreciate that knowing the structure of a substance can help us decide its applications.

Through activities such as gathering and analysing information about atomic structure and the Periodic Table, students should appreciate the impact of the discoveries of atomic structure and the development of the Periodic Table on modern chemistry. Students should also be able to appreciate that symbols and chemical formulae constitute part of the common language used by scientists to communicate chemical concepts.

Students should learn	Students should be able to
a. Atomic structure	
• elements, atoms and symbols • classification of elements into metals, non-metals and metalloids • electrons, neutrons and protons as subatomic particles • simple model of atom • atomic number (Z) and mass number (A)	• state the relationship between element and atom • use symbols to represent elements • classify elements as metals or non-metals on the basis of their properties • be aware that some elements possess characteristics of both metals and non-metals • state and compare the relative charges and the relative masses of a proton, a neutron and an electron

Students should learn	Students should be able to
• isotopes • isotopic masses and relative atomic masses based on ^{12}C=12.00 • electronic arrangement of atoms (up to Z=20) • stability of noble gases related to their electronic arrangements	• describe the structure of an atom in terms of protons, neutrons and electrons • interpret and use symbols such as $^{23}_{11}Na$ • deduce the numbers of protons, neutrons and electrons in atoms and ions with given atomic numbers and mass numbers • identify isotopes among elements with relevant information • perform calculations related to isotopic masses and relative atomic masses • understand and deduce the electronic arrangements of atoms • represent the electronic arrangements of atoms using electron diagrams • relate the stability of noble gases to the octet rule
b. The Periodic Table	
• the position of the elements in the Periodic Table related to their electronic arrangements • similarities in chemical properties among elements in Groups I, II, VII and 0	• understand that elements in the Periodic Table are arranged in order of ascending atomic number • appreciate the Periodic Table as a systematic way to arrange elements • define the group number and period number of an element in the Periodic Table • relate the position of an element in the Periodic Table to its electronic structure and vice versa • relate the electronic arrangements to the chemical properties of the Groups I, II, VII and 0 elements • describe differences in reactivity of Groups I, II and VII elements • predict chemical properties of unfamiliar elements in a group of the Periodic Table

Students should learn	Students should be able to
c. Metallic bonding	• describe the simple model of metallic bond
d. Structures and properties of metals	• describe the general properties of metals • relate the properties of metals to their giant metallic structures
e. Ionic and covalent bond • transfer of electrons in the formation of ionic bond • cations and anions • electron diagrams of simple ionic compounds • names and formulae of ionic compounds • ionic structure as illustrated by sodium chloride • sharing of electrons in the formation of covalent bond • single, double and triple bonds • electron diagrams of simple covalent molecules • names and formulae of covalent compounds • formula masses and relative molecular masses	• describe, using electron diagrams, the formation of ions and ionic bonds • draw the electron diagrams of cations and anions • predict the ions formed by atoms of metals and non-metals by using information in the Periodic Table • identify polyatomic ions • name some common cations and anions according to the chemical formulae of ions • name ionic compounds based on the component ions • describe the colours of some common ions in aqueous solutions • interpret chemical formulae of ionic compounds in terms of the ions present and their ratios • construct formulae of ionic compounds based on their names or component ions • describe the structure of an ionic crystal • describe the formation of a covalent bond • describe, using electron diagrams, the formation of single, double and triple bonds • describe the formation of the dative covalent bond by means of electronic diagram using H_3O^+ and NH_4^+ as examples • interpret chemical formulae of covalent compounds in terms of the elements present and the ratios of their atoms

Students should learn	Students should be able to
	• write the names and formulae of covalent compounds based on their component atoms • communicate scientific ideas with appropriate use of chemical symbols and formulae • define and distinguish the terms: formula mass and relative molecular mass • perform calculations related to formula masses and relative molecular masses of compounds
f. Structures and properties of giant ionic substances	• describe giant ionic structures of substances such as sodium chloride and caesium chloride • state and explain the properties of ionic compounds in terms of their structures and bonding
g. Structures and properties of simple molecular substances	• describe simple molecular structures of substances such as carbon dioxide and iodine • recognise that van der Waals' forces exist between molecules • state and explain the properties of simple molecular substances in terms of their structures and bonding
h. Structures and properties of giant covalent substances	• describe giant covalent structures of substances such as diamond, graphite and quartz • state and explain the properties of giant covalent substances in terms of their structures and bonding
i. Comparison of structures and properties of important types of substances	• compare the structures and properties of substances with giant ionic, giant covalent, simple molecular and giant metallic structures • deduce the properties of substances from their structures and bonding, and vice versa • explain applications of substances according to their structures

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for and presenting information on the discoveries related to the structure of an atom.
- searching for and presenting information on elements and the development of the Periodic Table.
- performing calculations related to relative atomic masses, formula masses and relative molecular masses.
- drawing electron diagrams to represent atoms, ions and molecules.
- investigating chemical similarities of elements in the same group of the Periodic Table (e.g. reactions of group I elements with water, group II elements with dilute hydrochloric acid, and group VII elements with sodium sulphite solution).
- predicting chemical properties of unfamiliar elements in a group of the Periodic Table.
- writing chemical formulae for ionic and covalent compounds.
- naming ionic and covalent compounds.
- exploring relationship of colour and composition of some gem stones.
- predicting colours of ions from a group of aqueous solutions (e.g. predicting colour of K^+(aq), $Cr_2O_7^{2-}$(aq) and Cl^-(aq) from aqueous solutions of potassium chloride and potassium dichromate).
- investigating the migration of ions of aqueous solutions, e.g. copper(II) dichromate and potassium permanganate, towards oppositely charged electrodes.
- building models of three-dimensional ionic crystals and covalent molecules.
- using computer programs to study three-dimensional images of ionic crystals, simple molecular substances and giant covalent substances.
- building models of diamond, graphite, quartz and iodine.
- predicting the structures of substances from their properties, and vice versa.
- justifying some particular applications of substances in terms of their structures.
- reading articles or writing essays on the applications of materials such as graphite and aluminium in relation to their structures.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to appreciate that scientific evidence is the foundation for generalisations and explanations about matter.
- to appreciate the usefulness of models and theories in helping to explain the structures and behaviours of matter.
- to appreciate the perseverance of scientists in developing the Periodic Table and hence to envisage that scientific knowledge changes and accumulates over time.
- to appreciate the restrictive nature of evidence when interpreting observed phenomena.
- to appreciate the usefulness of the concepts of bonding and structures in understanding phenomena in the macroscopic world, such as the physical properties of substances.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Using the universal conventions of chemical symbols and formulae facilitates communication among people in different parts of the world.
- Common names of substances can be related to their systematic names (e.g. table salt and sodium chloride; baking soda and sodium hydrogencarbonate).
- Some specialised new materials have been created on the basis of the findings of research on the structure, chemical bonding, and other properties of matters (e.g. bullet-proof fabric, superconductors and superglue).

III Metals

Overview

Metals have a wide range of uses in daily life. Therefore, the extraction of metals from their ores has been an important activity of human beings since prehistoric times. This topic provides opportunities for students to develop an understanding of how metals are extracted from their ores and how they react with other substances. Students are expected to establish a reactivity series of metals based on experimental evidence.

The corrosion of metals poses a socioeconomic problem to human beings. It is therefore necessary to develop methods to preserve the limited reserve of metals. An investigation of factors leading to corrosion and of methods to prevent metals from corroding is a valuable problem-solving exercise and can help students develop a positive attitude towards the use of resources on our planet.

A chemical equation is a concise and universally adopted way to represent a chemical reaction. Students should be able to transcribe word equations into chemical equations and appreciate that a chemical equation shows a quantitative relationship between reactants and products in a reaction. Students should also be able to perform calculations involving the mole and chemical equations. The mole concepts acquired from this topic prepare students for performing further calculations in other topics of the curriculum.

Students should learn	Students should be able to
a. Occurrence and extraction of metals	
• occurrence of metals in nature in free state and in combined forms	• state the sources of metals and their occurrence in nature
• obtaining metals by heating metal oxides or by heating metal oxides with carbon	• explain why extraction of metals is needed • understand that the extraction of metals involves reduction of their ores
• extraction of metals by electrolysis	• describe and explain the major methods of extraction of metals from their ores

Students should learn	Students should be able to
• relation of the discovery of metals with the ease of extraction of metals and the availability of raw materials • limited reserves of metals and their conservations	• relate the ease of obtaining metals from their ores to the reactivity of the metals • deduce the order of discovery of some metals from their relative ease of extraction • write word equations for the extraction of metals • describe metal ores as a finite resource and hence the need to recycle metals • evaluate the recycling of metals from social, economic and environmental perspectives
b. Reactivity of metals	
• reactions of some common metals (sodium, calcium, magnesium, zinc, iron, lead, copper, etc.) with oxygen/air, water, dilute hydrochloric acid and dilute sulphuric acid • metal reactivity series and the tendency of metals to form positive ions • displacement reactions and their interpretations based on the reactivity series • prediction of the occurrence of reactions involving metals using the reactivity series • relation between the extraction method of a metal and its position in the metal reactivity series	• describe and compare the reactions of some common metals with oxygen/air, water and dilute acids • write the word equations for the reactions of metals with oxygen/air, water and dilute acids • construct a metal reactivity series with reference to their reactions, if any, with oxygen/air, water and dilute acids • write balanced chemical equations to describe various reactions • use the state symbols (*s*), (*l*), (*g*) and (*aq*) to write chemical equations • relate the reactivity of metals to the tendency of metals to form positive ions • describe and explain the displacement reactions involving various metals and metal compounds in aqueous solutions • deduce the order of reactivity of metals from given information • write balanced ionic equations • predict the feasibility of metal reactions based on the metal reactivity series • relate the extraction method of a metal to its position in the metal reactivity series

Students should learn	Students should be able to
c. Reacting masses	
• quantitative relationship of the reactants and the products in a reaction as revealed by a chemical equation • the mole, Avogadro's constant and molar mass • percentage by mass of an element in a compound • empirical formulae and molecular formulae derived from experimental data • reacting masses from chemical equations	• understand and use the quantitative information provided by a balanced chemical equation • perform calculations related to moles, Avogadro's constant and molar masses • calculate the percentage by mass of an element in a compound using appropriate information • determine empirical formulae and molecular formulae from compositions by mass and molar masses • calculate masses of reactants and products in a reaction from the relevant equation and state the interrelationship between them • solve problems involving limiting reagents
d. Corrosion of metals and their protection	
• factors that influence the rusting of iron • methods used to prevent rusting of iron • socioeconomic implications of rusting of iron • corrosion resistance of aluminium • anodisation as a method to enhance corrosion resistance of aluminium	• describe the nature of iron rust • describe the essential conditions for the rusting of iron • describe and explain factors that influence the speed of rusting of iron • describe the observations when a rust indicator (a mixture of potassium hexacyanoferrate(III) and phenolphthalein) is used in an experiment that investigates rusting of iron • describe and explain the methods of rusting prevention as exemplified by i. coating with paint, oil or plastic ii. galvanising iii. tin-plating iv. electroplating v. cathodic protection vi. sacrificial protection vii. alloying

Students should learn	Students should be able to
	• be aware of the socio-economic impact of rusting • understand why aluminium is less reactive and more corrosion-resistant than expected • describe how the corrosion resistance of aluminium can be enhanced by anodisation

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for and presenting information about the occurrence of metals and their uses in daily life.
- analysing information to relate the reactivity of metals to the chronology of the Bronze Age, the Iron Age and the modern era.
- designing and performing experiments to extract metals from metal oxides (e.g. silver oxide, copper(II) oxide, lead(II) oxide, iron(III) oxide).
- deciding on appropriate methods for the extraction of metals from their ores.
- transcribing word equations into chemical equations.
- performing experiments to investigate reactions of metals with oxygen/air, water and dilute acids.
- constructing a metal reactivity series based on experimental evidence.
- performing experiments to investigate the displacement reactions of metals with aqueous metal ions.
- writing ionic equations.
- performing experiments to determine the empirical formula of magnesium oxide or copper(II) oxide.
- performing calculations related to moles and reacting masses.
- designing and performing experiments to investigate factors that influence rusting.
- performing experiments to study methods that can be used to prevent rusting.
- deciding on appropriate methods to prevent metal corrosion based on social, economic and technological considerations.
- searching for and presenting information about the metal-recycling industry of Hong Kong and the measures for conserving metal resources in the world.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to appreciate the contribution of science and technology in providing us with useful materials.
- to appreciate the importance of making fair comparisons in scientific investigations.
- to value the need for adopting safety measures when performing experiments involving potentially dangerous chemicals and violent reactions.
- to show concern for the limited reserve of metals and realise the need for conserving and using these resources wisely.
- to appreciate the importance of the mole concept in the study of quantitative chemistry.
- to appreciate the contribution of chemistry in developing methods of rust prevention and hence its socio-economic benefit.

STSE Connections

Students are encouraged to appreciate and to comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Although the steel industry has been one of the major profit-making industries in mainland China, there are many constraints on its growth, e.g. the shortage of raw materials in China.
- New technologies are being implemented to increase the efficiency of the metal extraction process and at the same time to limit their impacts on the environment.
- Conservation of metal resources should be promoted to arouse concern for environmental protection.
- The development of new alloys to replace pure metals is needed in order to enhance the performance of some products, such as vehicles, aircrafts, window frames and spectacles frames.

IV Acids and Bases

Overview

Acids and bases/alkalis are involved in numerous chemical processes that occur around us, from industrial processes to biological ones, and from reactions in the laboratory to those in our environment. Students have encountered acids and alkalis in their junior science courses. In this topic, they will further study the properties and reactions of acids and bases/alkalis, and the concept of molarity. Students should also be able to develop an awareness of the potential hazards associated with the handling of acids and alkalis.

Students will learn to use an instrumental method of pH measurement, to prepare salts by different methods, and to perform volumetric analysis involving acids and alkalis. Through these experimental practices students should be able to demonstrate essential experimental techniques, to analyse data and to interpret experimental results. Students are also expected to state the effects of concentration, temperature, surface area and the use of catalyst on the rate of reaction, and interpret results qualitatively from experiments of investigating factors affecting the rate of reaction. However, an interpretation at the molecular level and calculations are not expected.

Students should learn	**Students should be able to**
a. Introduction to acids and alkalis	
• common acids and alkalis in daily life and in the laboratory	• recognise that some household substances are acidic
• characteristics and chemical reactions of acids as illustrated by dilute hydrochloric acid and dilute sulphuric acid	• state the common acids found in laboratory • describe the characteristics of acids and their typical reactions • write chemical and ionic equations for the reactions of acids
• acidic properties and hydrogen ions ($H^+(aq)$)	• relate acidic properties to the presence of hydrogen ions ($H^+(aq)$)
• role of water in exhibiting properties of acid	• describe the role of water for acids to exhibit their properties
• basicity of acid	• state the basicity of different acids such as HCl, H_2SO_4, H_3PO_4, CH_3COOH
• characteristics and chemical reactions of alkalis as illustrated by sodium hydroxide and aqueous ammonia	• define bases and alkalis in terms of their reactions with acids

Students should learn	Students should be able to
• alkaline properties and hydroxide ions ($OH^-(aq)$) • corrosive nature of concentrated acids and concentrated alkalis	• recognise that some household substances are alkaline • state the common alkalis found in the laboratory • describe the characteristics of alkalis and their typical reactions • write chemical and ionic equations for the reactions of alkalis • relate alkaline properties to the presence of hydroxide ions ($OH^-(aq)$) • describe the corrosive nature of acids and alkalis and the safety precautions in handling them
b. Indicators and pH	
• acid-base indicators as exemplified by litmus, methyl orange and phenolphthalein • pH scale as a measure of acidity and alkalinity $pH = -log[H^+(aq)]$ • use of universal indicator and an appropriate instrument to measure the pH of solutions	• state the colours produced by litmus, methyl orange and phenolphthalein in acidic solutions and alkaline solutions • describe how to test for acidity and alkalinity using suitable indicators • relate the pH scale to the acidity or alkalinity of substances • perform calculations related to the concentration of $H^+(aq)$ and the pH value of a strong acid solution • suggest and demonstrate appropriate ways to determine pH values of substances
c. Strength of acids and alkalis	
• meaning of strong and weak acids as well as strong and weak alkalis in terms of their extent of dissociation in aqueous solutions • methods to compare the strength of acids/alkalis	• describe the dissociation of acids and alkalis • relate the strength of acids and alkalis to their extent of dissociation • describe acids and alkalis with the appropriate terms: strong and weak, concentrated and dilute • suggest and perform experiments to compare the strength of acids or alkalis

Students should learn	Students should be able to
d. Salts and neutralisation	
• bases as chemical opposites of acids • neutralisation as the reaction between acid and base/alkali to form water and salt only • exothermic nature of neutralisation • preparation of soluble and insoluble salts • naming of common salts • applications of neutralisation	• write chemical and ionic equations for neutralisation • state the general rules of solubility for common salts in water • describe the techniques used in the preparation, separation and purification of soluble and insoluble salts • suggest a method for preparing a particular salt • name the common salts formed from the reaction of acids and alkalis • explain some applications of neutralisation
e. Concentration of solutions	
• concentration of solutions in mol dm^{-3} (molarity)	• convert the molar concentration of solutions to g dm^{-3} • perform calculations related to the concentration of solutions
f. Volumetric analysis involving acids and alkalis	
• standard solutions • acid-alkali titrations	• describe and demonstrate how to prepare solutions of required concentration by dissolving a solid or diluting a concentrated solution • calculate the concentrations of the solutions prepared • describe and demonstrate the techniques of performing acid-alkali titration • apply the concepts of concentration of solution and use the results of acid-alkali titrations to solve stoichiometric problems • communicate the procedures and results of a volumetric analysis experiment by writing a laboratory report

Students should learn	Students should be able to
g. Rate of chemical reaction	
• factors affecting rate of reaction: i. concentration ii. temperature iii. surface area iv. catalyst	• interpret results (e.g. graphs) qualitatively from experiments on factors affecting rate of reaction: changes in volume / pressure of gases, mass of a mixture and turbidity of a mixture • state the effect of concentration, temperature, surface area and the use of catalyst on the rate of reaction

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for examples of naturally occurring acids and bases, and their chemical composition.
- investigating the actions of dilute acids on metals, carbonates, hydrogencarbonates, metal oxides and metal hydroxides.
- designing and performing experiments to study the role of water in exhibiting properties of acids.
- searching for information about the hazardous nature of acids/alkalis.
- investigating the action of dilute alkalis on aqueous metal ions to form metal hydroxide precipitates.
- investigating the action of dilute alkalis on ammonium compounds to give ammonia gas.
- performing experiments to investigate the corrosive nature of concentrated acids/alkalis.
- searching for information about the nature of common acid-base indicators.
- performing experiments to find out the pH values of some domestic substances.
- measuring pH values of substances by using data logger or pH meter.
- designing and performing experiments to compare the strengths of acids/alkalis.
- investigating the temperature change in a neutralisation process.
- preparing and isolating soluble and insoluble salts.
- searching for and presenting information on applications of neutralisation.
- preparing a standard solution for volumetric analysis.
- performing calculations involving molarity.
- performing acid-alkali titrations using suitable indicators/pH meter/data logger.

- using a titration experiment to determine the concentration of acetic acid in vinegar or the concentration of sodium hydroxide in drain cleaner.
- performing calculations on titrations.
- writing a detailed report for an experiment involving volumetric analysis.
- searching for information on accident(s) caused by the failure to control reaction rate.
- performing experiments to study the effect of concentration, temperature and surface area; and the use of catalyst on the rate of reaction.
- searching for information or reading articles on airbags of vehicles.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to develop a positive attitude towards the safe handling, storage and disposal of chemicals, and hence adopt safe practices.
- to appreciate the importance of proper laboratory techniques and precise calculations for obtaining accurate results.
- to appreciate that volumetric analysis is a vital technique in analytical chemistry.
- to appreciate the importance of controlling experimental variables in making comparisons.
- to appreciate the use of instruments in enhancing the efficiency and accuracy of scientific investigation.
- to value the need to control reaction rates for human advancement.
- to appreciate that a problem can be solved by diverse approaches.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Measures involving neutralisation have been implemented to control the emission of nitrogen oxides and sulphur dioxide from vehicles, factories and power stations.
- Caustic soda is manufactured by the chloroalkali industry which is a traditional chemical raw materials industry.
- Volumetric analysis, as an essential technique in analytical chemistry is applied in testing laboratories and forensic chemistry.
- Antacid is a common drug which contains base(s) for neutralising stomach acid and therefore relieving stomachache.

- Control of metal corrosion has socio-economic importance and environmental relevance.
- Research into reaction rates has made a positive contribution to society, e.g. airbags in vehicles.
- Research into reaction rates is closely linked with the development of lethal weapons.

V Fossil Fuels and Carbon Compounds

Overview

Carbon compounds play an important role in industry and in daily life. Coal and petroleum are two major sources of carbon compounds. In this topic, the main focus is placed on the use of petroleum fractions as fuel and as a source of hydrocarbons. Students should appreciate that the use of fossil fuels has brought us benefits and convenience, such as providing us with domestic fuels and raw materials for making synthetic polymers like plastics and synthetic fibers, alongside environmental problems such as air pollution, acid rain, and the global warming. Eventually, they should realise that human activities can have a significant impact on our environment.

This topic also introduces some basic concepts of organic chemistry such as homologous series, functional group, general formula and structural formula. Students should be able to give systematic names of alkanes, alkenes, alkanols and alkanoic acids with carbon chains not more than four carbon atoms. In addition, they are expected to learn the chemical reactions of alkanes, alkenes, alkanols and alkanoic acids. By illustrating the formation of monosubstituted halomethane with electron diagrams, students should realise that chemical reactions often take place in more than one step and involve reactive species.

Polymers can be synthesised by reacting small organic molecules (monomer) together in a chemical reaction. This process is called polymerisation. Students should understand the formation of addition and condensation polymers. Also, they should realise that the uses of some common polymers can be related to their physical properties which are, in turn, related to their structures.

Students should learn	Students should be able to
a. Hydrocarbons from fossil fuels	
• coal, petroleum and natural gas as sources of fossil fuels and carbon compounds • composition of petroleum and its separation • gradation in properties of the various fractions of petroleum • heat change during combustion of hydrocarbons • major uses of distilled fractions of petroleum • consequences of using fossil fuels	• describe the origin of fossil fuels • describe petroleum as a mixture of hydrocarbons and its industrial separation into useful fractions by fractional distillation • recognise the economic importance of petroleum as a source of aliphatic and aromatic hydrocarbons (e.g. benzene) • relate the gradation in properties (e.g. colour, viscosity, volatility and burning characteristics) with the number of carbon atoms in the molecules of the various fractions • explain the demand for the various distilled fractions of petroleum • recognise combustion of hydrocarbons as an exothermic chemical reaction • recognise the pollution from the combustion of fossil fuels • evaluate the impact of using fossil fuels on our quality of life and the environment • suggest measures for reducing the emission of air pollutants from combustion of fossil fuels
b. Homologous series, structural formulae and naming of carbon compounds	
• unique nature of carbon • homologous series as illustrated by alkanes, alkenes, alkanols and alkanoic acids • structural formulae and systematic naming of alkanes, alkenes, alkanols and alkanoic acids	• explain the large number and diversity of carbon compounds with reference to carbon's unique combination power and ability to form different bonds • explain the meaning of a homologous series • understand that members of a homologous series show a gradation in physical properties and similarity in chemical properties

Students should learn	Students should be able to
	• write structural formulae of alkanes • give systematic names of alkanes • extend the knowledge of naming carbon compounds and writing structural formulae to alkenes, alkanols and alkanoic acids
c. Alkanes and alkenes • petroleum as a source of alkanes • alkanes • cracking and its industrial importance • alkenes	• distinguish saturated and unsaturated hydrocarbons from the structural formulae • describe the following reactions of alkanes and write the relevant chemical equations: i. combustion ii. substitution reactions with chlorine and bromine, as exemplified by the reaction of methane and chlorine (or bromine) • describe the steps involved in the monosubstitution of methane with chlorine using electron diagrams • recognise that cracking is a means to obtain smaller molecules including alkanes and alkenes • describe how to carry out laboratory cracking of a petroleum fraction • explain the importance of cracking in the petroleum industry • describe the reactions of alkenes with the following reagents and write the relevant chemical equations: i. bromine ii. potassium permanganate solution • demonstrate how to carry out chemical tests for unsaturated hydrocarbons

Students should learn	Students should be able to
d. Alcohols, alkanoic acids and esters • Uses of alcohols • Reactions of alkanols • Uses of esters	• state some common uses of alcohols, e.g. in drinks, as solvents and fuels • describe the reactions of alkanols with i. acidified potassium dichromate to produce alkanoic acids ii. alkanoic acids to produce esters • state some common uses of esters, e.g. as fragrances, flavourings and solvents
e. Addition polymers and condensation polymers • monomers, polymers and repeating units • addition polymerisation • condensation polymerisation • structure, properties and uses of polymers as illustrated by polyethene, polypropene, polyvinyl chloride, polystyrene, Perspex, nylon and polyesters	• recognise that synthetic polymers are built up from small molecules called monomers • recognise that alkenes, unsaturated compounds obtainable from cracking of petroleum fractions, can undergo addition reactions • understand that alkenes and unsaturated compounds can undergo addition polymerisation • deduce the type of polymerisation reaction for a given monomer or a pair of monomers • write equations for the formation of addition and condensation polymers • deduce the repeating unit of a polymer obtained from a given monomer or a pair of monomers • deduce the monomer or a pair of monomers from a given section of a formula of a polymer

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for and presenting information about the locations of deposits of coal, petroleum and natural gases in China and other countries.
- investigating colour, viscosity, volatility and burning characteristics of petroleum fractions.
- searching for and presenting information about petroleum fractions regarding their major uses and the relation between their uses and properties.
- discussing the relationship between global warming and the use of fossil fuels.
- drawing structural formulae and writing systematic names for alkanes, alkenes, alkanols and alkanoic acids.
- building molecular models of simple alkanes, alkenes, alkanols and alkanoic acids.
- performing experiments to investigate the typical reactions of alkanes and alkenes.
- studying the nature of the substitution reaction of methane and halogen with the aid of relevant video or computer animation.
- performing an experiment on cracking of a petroleum fraction and testing the products.
- searching for information and presenting arguments on the risks and benefits of using fossil fuels to the society and the environment.
- discussing the pros and cons of using alternative sources of energy in Hong Kong.
- preparing ethanoic acid or ethyl ethanoate.
- searching for information or reading articles about the discovery of polyethene and the development of addition polymers.
- investigating properties such as the strength and the ease of softening upon heating of different plastics.
- writing chemical equations for the formation of polymers based on given information.
- building physical or computer models of polymers.
- deducing the monomer(s) from the structure of a given polymer.
- performing an experiment to prepare an addition polymer e.g. polystyrene, Perspex.
- performing an experiment to prepare a condensation polymer e.g. nylon.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to appreciate the importance of organising scientific information in a systematic way.
- to recognise the benefits and impacts of the application of science and technology.

- to value the need for the conservation of the Earth's resources.
- to appreciate the need for alternative sources of energy for sustainable development of our society.
- to value the need for the safe use and storage of fuels.
- to appreciate the versatility of synthetic materials and the limitations of their use.
- to show concern for the environment and develop a sense of shared responsibility for sustainable development of our society.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- The petroleum industry provides us with many useful products that have improved our standard of living. However, there are risks associated with the production, transportation, storage and usage of fossil fuels.
- Emissions produced from the burning of fossil fuels are polluting the environment and are contributing to long-term and perhaps irreversible changes in the climate.
- There are many examples of damages uncovered after using the applications of science and technology for a long period, e.g. the pollution problem arising from using leaded petrol and diesel; and the disposal problem for plastics. Therefore, it is essential to carefully assess the risks and benefits to society and the environment before actually using those applications of science and technology in daily life.

VI Redox Reactions, Chemical Cells and Electrolysis

Overview

Chemical reactions involve the release or absorption of energy, which often appear in the form of heat, light or electrical energy. In a chemical cell, chemical energy is converted to electrical energy. The flow of electrons in an external circuit indicates the occurrence of reduction and oxidation (redox) at the electrodes. To help students understand the chemistry involved in a chemical cell, the concept of redox reactions is introduced in this topic. Students will carry out investigations involving common oxidising and reducing agents. They will also learn how to write chemical equations for redox reactions.

With the concepts related to redox reactions, students should be able to understand the reactions occurring in more complicated chemical cells and the processes involved in electrolysis. Students should also appreciate that the feasibility of a redox reaction can be predicted by comparing the different positions of the species in the electrochemical series. In addition, students should be able to predict products in electrolysis according to the different factors affecting the preferential discharge of ions.

The concepts of redox reactions have a number of applications in industrial chemistry and daily life. Students should appreciate the contribution of electrochemistry to technological innovations, which in turn improve our quality of life. Students should also be able to assess the environmental impact and safety issues associated with these technologies.

Students should learn	Students should be able to
a. Chemical cells in daily life	
• primary cells and secondary cells	• distinguish between primary and secondary cells
• uses of chemical cells in relation to their characteristics such as size, voltage, capacity, rechargeability and price	• describe the characteristics of common primary and secondary cells: i. zinc-carbon cell ii. alkaline manganese cell iii. silver oxide cell

Students should learn	Students should be able to
	iv. lithium ion cell v. nickel metal hydride (NiMH) cell vi. lead-acid accumulator • justify uses of different chemical cells for particular purposes • understand the environmental impact of using dry cells
b. Reactions in simple chemical cells	
• chemical cells consisting of: i. two metal electrodes and an electrolyte ii. metal-metal ion half cells and salt bridge/porous device • changes occurring at the electrodes and electron flow in the external circuit • half equations and overall cell equations	• describe and demonstrate how to build simple chemical cells using metal electrodes and electrolytes • measure the voltage produced by a chemical cell • explain the problems associated with a simple chemical cell consisting of two metal electrodes and an electrolyte • explain the functions of a salt bridge/porous device • describe and demonstrate how to build simple chemical cells using metal-metal ion half cells and salt bridges/porous devices • explain the differences in voltages produced in chemical cells when different metal couples are used as electrodes • write a half equation representing the reaction at each half cell of a simple chemical cell • write overall equations for simple chemical cells • predict the electron flow in the external circuit and the chemical changes in the simple chemical cells

Students should learn	Students should be able to
c. Redox reactions	
• oxidation and reduction • oxidation numbers • common oxidising agents (e.g. MnO_4^-(aq)/H^+(aq), $Cr_2O_7^{2-}$(aq)/H^+(aq), Fe^{3+}(aq), Cl_2(aq), HNO_3(aq) of different concentrations and conc. H_2SO_4(l)) • common reducing agents (e.g. SO_3^{2-}(aq), I^-(aq), Fe^{2+}(aq), Zn(s)) • balancing equations for redox reactions	• identify redox reactions, oxidising agents and reducing agents on the basis of i. gain or loss of oxygen/hydrogen atom(s) ii. gain or loss of electron(s) iii. changes in oxidation numbers • assign oxidation numbers to the atoms of elements and compounds • construct a general trend of the reducing power of metals and the oxidising power of metal ions • describe the chemical changes of some common oxidising agents and reducing agents • relate the trends of the reducing power and oxidising power of chemical species to their positions in a given electrochemical series • balance half equations of reduction and oxidation balance redox equations by using half equations or changes in oxidation numbers

Students should learn	Students should be able to
d. Redox reactions in chemical cells	
• zinc-carbon cell • chemical cells with inert electrodes • fuel cell	• describe the structure of a zinc-carbon dry cell • write the half equation for reaction occurring at each electrode and the overall equation for reaction in a zinc-carbon dry cell • describe and construct chemical cells with inert electrodes • predict the chemical changes at each half cell of the chemical cells with inert electrodes • write half equation for reaction occurring at each half cell and the overall ionic equation for reaction in the chemical cells with inert electrodes • understand the principles of hydrogen-oxygen fuel cell • write the half equation for reaction occurring at each electrode and the overall equation for reaction in a hydrogen-oxygen fuel cell • state the pros and cons of a hydrogen-oxygen fuel cell
e. Electrolysis	
• electrolysis as the decomposition of substances by electricity as exemplified by electrolysis of i. dilute sulphuric acid ii. sodium chloride solutions of different concentrations iii. copper(II) sulphate solution • anodic and cathodic reactions • preferential discharge of ions in relation to the electrochemical series, concentration of ions and nature of electrodes • industrial applications of electrolysis: i. electroplating ii. purification of copper	• describe the materials needed to construct an electrolytic cell • predict products at each electrode of an electrolytic cell with reference to the factors affecting the preferential discharge of ions • describe the anodic and cathodic reactions, overall reaction and observable changes of the electrolyte in electrolytic cells • understand the principles of electroplating and the purification of copper • describe the anodic and cathodic reactions, overall reaction and observable changes of electrolyte in electroplating and the purification of copper • understand the environmental impact of the electroplating industry

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- making decisions on the choice of chemical cells in daily life based on available information.
- making simple chemical cells and measuring their voltages.
- writing ionic half equations.
- performing experiments to investigate redox reactions with common oxidising and reducing agents.
- determining oxidation numbers of atoms in elements and compounds.
- balancing redox equations by using ionic half equations or by using oxidation numbers.
- investigating redox reactions of concentrated sulphuric acid with metals.
- investigating redox reactions of nitric acid of different concentrations with metals.
- searching for and presenting information about the applications of fuel cells.
- investigating the working principles of a fuel cell model car.
- performing experiment to investigate the working principles of a lead-acid accumulator.
- predicting changes in chemical cells based on given information.
- viewing or constructing computer simulations illustrating the reactions in chemical cells.
- performing experiments to investigate changes in electrolysis.
- performing experiments to investigate factors affecting preferential discharge of ions during electrolysis.
- searching for and presenting information about the possible adverse impact of the electroplating industry on the environment.
- designing and performing electroplating experiments.
- reading articles about the industrial processes involved in the extraction of aluminium from aluminium ore.
- discussing the pros and cons of using hydrogen-oxygen fuel cells in vehicles.
- investigating the chemistry involved in oxygen absorbers of packaged food.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to value the contribution of technological innovations to the quality of life.
- to appreciate the usefulness of the concept of oxidation number in the study of redox reactions.
- to develop a positive attitude towards the safe handling, storage and disposal of chemicals, and hence adopt safe practices.
- to value the need for assessing the impact of technology on our environment.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Various breath-testing technologies, such as passive alcohol sensors, preliminary breath tests, and evidentiary breath tests (e.g. the intoximeter EC/IR) all utilise fuel cell technology to detect alcohol.
- Hydrogen-oxygen fuel cells are being used for some areas like space missions and vehicles, but not widely for commercial or domestic purposes.
- Lithium cell chemistry variants, such as lithium-ion battery, lithium-ion polymer battery, lithium cobalt battery, lithium manganese battery and lithium nickel battery, have been developed to cope with the need for a wide range of consumer products.
- Many electrolytic processes are involved in industrial processes, e.g. refining of metals, the chloroalkali industry and the aluminium production from ore (bauxite).
- The development of electrolysis in extracting reactive metals is closely related to human history.

VII Chemical Reactions and Energy

Overview

Chemical reactions are accompanied by energy changes, which often appear in the form of heat. In fact, energy absorbed or released by a chemical system may take different forms. Basic concepts of chemical energetics and enthalpy terms are introduced in this topic. Practical work on the simple calorimetric method and quantitative treatment of Hess's law can help students to better understand the concepts of energetics. However, the use of equipment such as the bomb calorimeter is not expected at this level of study.

Students should learn	Students should be able to
a. Energy changes in chemical reactions	
• conservation of energy • endothermic and exothermic reactions and their relationship to the breaking and forming of bonds	• explain energy changes in chemical reactions in terms of the concept of conservation of energy • describe enthalpy change, ΔH, as heat change at constant pressure • explain diagrammatically the nature of exothermic and endothermic reactions in terms of enthalpy change • explain the nature of exothermic and endothermic reactions in terms of the breaking and forming of chemical bonds
b. Standard enthalpy changes of reactions	• explain and use the terms: enthalpy change of reaction and standard conditions, with particular reference to neutralisation, formation and combustion • carry out experimental determination of enthalpy changes using simple calorimetric method • calculate enthalpy changes from experimental results

Students should learn	Students should be able to
c. Hess's law	
• use of Hess's law to determine enthalpy changes which cannot be easily determined by experiment directly • calculations involving enthalpy changes of reactions	• apply Hess's law to construct simple enthalpy change cycles • perform calculations involving such cycles and relevant energy terms, with particular reference to determining enthalpy change that cannot be found directly by experiment

Suggested Learning and Teaching Activities

Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- using appropriate methods and techniques to design and carry out determination of standard enthalpy change of (a) acid-base neutralisation and (b) combustion of alcohols.
- constructing enthalpy change cycles to quantitatively relate, according to Hess's law, reaction enthalpy changes and other standard enthalpy changes.
- discussing the limitations of simple calorimetric methods as opposed to other more sophisticated techniques.
- performing calculations on standard enthalpy change of reactions involving (a) standard enthalpy change of formation, (b) standard enthalpy change of combustion and (c) other standard enthalpy terms.
- performing experiments to determine the enthalpy change of formation of metal oxides or metal carbonates.
- finding out different approaches to solving problems of standard enthalpy changes in chemical reactions.
- investigating the chemistry involved in hand-warmers or cold-packs.

Values and Attitudes

Students are expected to develop, in particular, the following *values and attitudes*:

- to value the need to understand heat changes in chemical reactions in a systematic way.
- to appreciate the importance of interdisciplinary relevance, e.g. knowledge of quantitative treatment in thermal physics is involved in enthalpy change calculations.
- to accept quantitative experimental results within tolerance limits.

STSE Connections

Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Humans have been making efforts to discover more efficient release of thermal energy from chemical reactions, e.g. combustion of fuels.
- The ever-increasing use of thermal energy from chemical reactions has impacts on technology and the environment, e.g. energy crisis and global warming.
- Energy changes in chemical reactions have been utilised in many daily life products, e.g. hand-warmers, physiotherapy heat-packs, cold-packs, self-heating coffee and lunchboxes.
- The difficulty in harnessing solar energy, and in storing it chemically are the challenges in using alternative energy sources.

Part 3: Biology

I Cells and Molecules of Life

Overview

Cells and biomolecules are fundamental units of life. Organisms are built up of these fundamental units which function as an integrated whole. The study of the structure and function of cells will lay the foundation for students to understand and relate cellular processes to the essential life processes of organisms. The study of the discovery of cells will enable students to appreciate the contribution of technology to the advancement of science and the dynamic nature of biological knowledge.

Scientific Inquiry

This should enable students to:

- ask relevant questions, identify problems and formulate hypotheses for investigations related to cells and molecules of life;
- plan and conduct scientific investigations in the area of cellular structures and functions;
- use appropriate instruments and proper techniques for carrying out practical work (e.g. food tests, preparation of temporary mounts and microscopic examination);
- make careful observations and accurate records (e.g. examine prepared slides or temporary mounts of tissues and make biological drawings); and
- identify and explain the importance of control variables in scientific investigations (e.g. the study of enzymatic activities and osmosis).

STSE Connections

This should enable students to:

- be aware of the applications of biological knowledge of cells and molecules of life in society;
- appreciate the role of science and technology in understanding the molecular basis of life; and
- recognise that the development of microscopic technology, computing technology and image analysing technology may lead to the advancement of biological knowledge.

Nature and History of Biology

This should enable students to:

- be aware of the dynamic nature of biological knowledge (e.g. the understanding of cell membrane, sub-cellular organelles and cellular processes);
- recognise the contributions of various people (e.g. Robert Hooke and Theodor Schwann) to developments in biology; and
- be aware that biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. fluid mosaic model of cell membrane structure).

Students should learn	Students should be able to
a. Molecules of life	
Water and inorganic ions (e.g. nitrogen, magnesium, calcium and iron) Biomolecules: carbohydrates, lipids, proteins and nucleic acids • Building blocks • Functions	• Relate the significance of water, inorganic ions and biomolecules to life.
b. Cellular organisation	
Discovery of cells Cell membrane • Properties and functions Sub-cellular structures and their functions • Nucleus and chromosomes, endoplasmic reticulum, mitochondrion, chloroplast, cell wall and vacuole Prokaryotic cells (e.g. bacterial cells) and eukaryotic cells	• Appreciate the contribution of technological development of the microscope to the discovery of cells. • Prepare temporary mounts of specimens for examination, and make observations and drawings under a light microscope. • Use the fluid mosaic model to explain the properties and functions of cell membrane. • Appreciate the uses and limitations of scientific models. • Compare the cellular organisation of animal and plant cells. • Identify cell organelles as seen under light and electron microscopes.

Students should learn	Students should be able to
	• Compare the sub-cellular organisation of prokaryotic and eukaryotic cells.
c. Movement of substances across membrane	
Diffusion, osmosis and active transport Occurrences of phagocytosis in cells	• Account for the movement of substances across membrane using the concepts of diffusion, osmosis and active transport. • Apply the concept of osmosis to explain plasmolysis and haemolysis.
d. Cell cycle and division	
Stages of cell cycle • Cell growth, nuclear division and cytoplasmic division Nuclear division • Mitosis • Meiosis	• Understand the importance of cell division in growth and reproduction. • Recognise the various stages of cell cycle. • Outline and compare the processes of mitosis and meiosis.
e. Cellular energetics	
Metabolism: catabolism and anabolism • Occurrence of catabolic and anabolic processes in cells Enzymes and enzymatic reactions • Properties and roles of enzyme • Active site and specificity • Factors (temperature, pH and inhibitors) affecting the rate of enzymatic reactions • Application of enzyme in everyday life	• Distinguish between catabolic and anabolic processes. • Recognise the properties of enzyme and its roles in metabolism. • Explain enzyme specificity in terms of active site. • Explain the effects of factors on the rate of enzymatic reactions.

Suggested Learning and Teaching Activities

a. Molecules of life

- Discuss whether life can exist without water, and the possible benefits of drinking mineral water or isotonic drinks.
- Perform common biochemical tests (e.g. Benedict's test, iodine test, grease spot test, and different types of test papers) to identify the presence of biomolecules in living tissues.

b. Cellular organisation

- Read articles about the discovery of cells.
- Conduct a project to explore the contribution of the development of the microscope to the understanding of cells.
- Discuss the variations of the number of mitochondria in different tissues and cell types.
- Prepare temporary mounts of animal and plant tissues for examination under a light microscope.
- Examine electron micrographs or live cell images of prokaryotic, eukaryotic cells and sub-cellular structures.
- Construct a model to represent the structure of cell membrane (e.g. using tank and ping-pong balls).

c. Movement of substances across membrane

- Perform practical work to study osmosis at cellular, tissue or organ levels.
- Examine live cell images of the processes involved in the movement of substances across membrane.

d. Cell cycle and division

- Observe and identify the different stages of mitosis and meiosis, using prepared slides, photomicrographs or live cell images.

e. Cellular energetics

- Perform practical work to demonstrate the breaking down or building up action of enzymes.
- Design and perform investigations to study the effects of temperature, pH or inhibitors on the activities of enzymes; and to find out some commercial applications of enzymes (e.g. bioactive washing powder and meat tenderiser).

II Genetics and Evolution

Overview

Through the study of basic genetics, students will acquire knowledge and develop an understanding of concepts of genes and their roles in the life of organisms. The study of molecular genetics will lay the foundation for students to study further in the field of biotechnology and be aware of its impact on society.

The study of biodiversity will help students to recognise its complexity and the adaptations of different groups of organisms to their environment. Moreover, a phylogenetic approach to the classification system is adopted, which helps them to understand the development of the classification system with evidence gathered from molecular genetics. This will enable students to appreciate the phenomena of evolution and develop their curiosity about the origins of life. In addition to Darwin's theory, students are encouraged to explore other scientific explanations for the origins of life and evolution, to help illustrate the dynamic nature of scientific knowledge.

Scientific Inquiry

This should enable students to:

- make careful observations and accurate records (e.g. observe distinguishing features for identifying organisms, and variations in humans);
- use appropriate instruments and proper techniques for carrying out practical work on molecular genetics (e.g. DNA extraction and gel-electrophoresis);
- classify, collate and display both first and second hand data (e.g. construct a pedigree of the inheritance of some human traits);
- use diagrams and physical models as visual representations of phenomena and relationships arising from the data (e.g. genetic diagrams and DNA model); and
- formulate and revise scientific explanations and models using logic and evidence (e.g. use of fossil records as evidence for evolution).

STSE Connections

This should enable students to:

- be aware of the application of knowledge of basic and molecular genetics in society and its social, ethical and economic implications;

- be aware that societal needs have led to technological advances (e.g. recombinant DNA technology and DNA fingerprinting);
- appreciate the contribution of the Human Genome Project (HGP) and the application of biotechnology to humans and society;
- appreciate the role of science and technology in understanding the complexity of life forms and their genetics;
- understand how science has been influenced by societies (e.g. various views on the origins of life and evolution); and
- explain how the knowledge of biotechnology may lead to the development of new technologies and how new technologies may lead to further understanding of inheritance.

Nature and History of Biology

This should enable students to:

- be aware of the dynamic nature of biological knowledge (e.g. from basic genetics to molecular genetics, and the development of classification systems);
- recognise the contributions of various people (e.g. Gregor Mendel, James Watson, Francis Crick, Charles Darwin, Sir Alfred Russel Wallace and Jean Baptiste Lamarck) to the understanding of genetics and evolution;
- appreciate the advancement of the study of genetics from traditional breeding experiments to molecular experimentation and analysis; and
- be aware that biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. Mendel's work).

Students should learn	Students should be able to
a. Basic genetics	
Mendel's laws of inheritance	• Understand the law of segregation and law of independent assortment.
Inheritance in humans • Multiple alleles: ABO blood groups • Sex linkage • Sex determination	• Apply Mendel's laws of inheritance to solve genetic problems. • Understand the inheritance of ABO blood groups and sex-linked traits. • Recognise the role of sex chromosomes in sex determination of humans.
Pedigree analysis	• Analyse pedigree to study the inheritance of characteristics.

Students should learn	Students should be able to
Variations in characteristics • Continuous variation • Discontinuous variation • Causes of variation – hereditary information – environmental factors – mutation	• Explain the causes of different types of variations in characteristics.
b. Molecular genetics	
Chromosomes, genes and nucleic acids	• Describe the structural and functional relationships of chromosomes, genes and nucleic acids.
Biotechnology • Recombinant DNA technology • DNA fingerprinting • Human Genome Project (HGP) and its implications	• Recognise the applications of recombinant DNA technology and DNA fingerprinting. • Recognise the contributions and limitations of the data obtained from the HGP. • Appreciate the joint effort of scientists in international genomics projects.
c. Biodiversity and evolution	
Diversity of life forms	• Appreciate the existence of various life forms in the world, and the different ways through which organisms adapt to their habitats.
Classification of organisms • Need for classification • Classification approaches proposed by Carl Woese – Six kingdoms (Eubacteria, Archaebacteria, Protista, Fungi, Plantae and Animalia) – Three domains (Bacteria, Archaea and Eukarya)	• Be aware that modern classification is based on the phylogenetic relationships of organisms. • Appreciate that classification systems are subject to change when new evidence appears. • Recognise the use of classification systems and binomial nomenclature. • Construct and use dichotomous keys to identify unknown organisms. • Classify organisms into six kingdoms.
Origins of life	• Appreciate that there are various explanations for the origins of life.
Evolution • Origin of species • Evidence of evolution (e.g. fossil record)	• Be aware of the limitations of using fossil record as evidence of evolution, and the presence of other evidence.

Suggested Learning and Teaching Activities

a. Basic genetics

- Read articles about how Gregor Mendel contributed to the study of genetics.
- Use computer simulations and other materials (e.g. genetic corn) to study patterns of inheritance.
- Observe and analyse variations in humans (e.g. height and tongue rolling).
- Construct and/or a pedigree of the inheritance of some human traits (e.g. haemophilia, tongue rolling and ear lobes).

b. Molecular genetics

- Construct models of DNA and RNA.
- Read about the work of some biologists (e.g. James Watson and Francis Crick) in the discovery of DNA.
- Use audiovisual materials to illustrate the processes of recombinant DNA technology and DNA fingerprinting.
- Perform practical work to extract DNA from living tissues (e.g. onion tissues); and to separate DNA fragments by gel-electrophoresis.
- Search for information on the use of DNA fingerprinting in forensic science.
- Make a chart or create a timeline of the discoveries that have arisen from the HGP.

c. Biodiversity and evolution

- Visit a herbarium, country park or special area (e.g. Lions Nature Education Centre, and Tai Po Kau Nature Reserve).
- Use specimens, audiovisual materials, games, etc. to study the diversity of organisms, and their ways of life.
- Classify organisms into major categories according to a classification system.
- Discuss the advantages and limitations of different classification systems, and why the classification of some organisms has been changed over time.
- Search for information on other classification systems; and binomial naming of some organisms.
- Construct and use dichotomous keys to identify organisms from a local habitat.
- Read about the work of Carl Linnaeus and his system of naming organisms; the different explanations for the origins of life; and the work of some biologists (e.g. Jean Baptiste Lamarck, Charles Darwin and Sir Alfred Russel Wallace) on evolution.

III Organisms and Environment

Overview

Organisms are an integral part of the environment. Their ways of life and living are closely related to the environment where they live in. Based on this perspective, students will gain knowledge and understanding of organisms and their environment.

Firstly, students will study how organisms obtain their basic needs for oxygen, water and food from the environment. Life processes, such as nutrition, gas exchange, and transport involved, will be studied in an integrated manner so as to enhance understanding of the structures and function of an organism as a whole. Secondly, students will study reproduction, growth and development to understand how organisms perpetuate and proliferate in the environment. The human is used as a model for students to understand the essential life processes of animals. Thirdly, students will examine how organisms detect changes in the environment and make appropriate responses for their survival, and how humans maintain a steady internal environment. Students will then explore how organisms interact with each other and with their environment as a whole. Finally, the dynamic nature of the ecosystems that involves energy flow and materials cycling will also be investigated. Students are expected to develop an awareness of the impact of human activities on the ecosystems and recognise the need for conservation.

Scientific Inquiry

This should enable students to:

- make careful observations and accurate records (e.g. examine prepared slides or temporary mounts of roots, stems and leaves, and make biological drawings);
- ask relevant questions, identify problems and formulate hypotheses for investigations related to life processes and ecosystems;
- plan, conduct and write reports on scientific investigations in areas of life processes and ecosystems;
- select and design appropriate methods of investigations for specific purposes (e.g. use transects and quadrats to collect samples in field studies);
- identify and explain the importance of control variables in scientific investigations (e.g. the study of the effects of different minerals on plant growth, and the action of digestive enzymes);

- explain why sample size, random sampling, replicates and repeat procedures are important in scientific investigations (e.g. field studies);
- use appropriate instruments and proper techniques for carrying out practical work (e.g. food tests, preparation of temporary mounts, microscopic examinations, dissections and field study techniques); and
- use diagrams, graphs, flow charts and physical models as visual representations of phenomena and relationships arising from the data (e.g. use food chains, food webs, and pyramid of numbers to represent relationships between organisms in ecosystems and distribution of organisms).

STSE Connections

This should enable students to:

- evaluate the impact of the application of biology to human activities (e.g. dietary requirement, birth control and pollution control);
- analyse ways in which scientific and technological advancement (e.g. computing technology and image analysing technology) have enhanced our understanding of complex life processes;
- develop sensitivity and responsibility in striking a balance between the needs of humans and a sustainable environment; and
- be aware of the application of biological knowledge (e.g. balanced diet, birth control and sewage treatment) in society and its social, ethical, economic and environmental implications.

Nature and History of Biology

This should enable students to:

- understand that science is a human endeavour through the study of essential life processes of organisms and interactions within our environment;
- be aware that biological knowledge and theories are developed through observations, hypotheses, experimentations, and analyses (e.g. the study of tropism, transpiration pull and field ecology);
- recognise the complexity of the physiological processes of organisms and the environment; and
- understand the nature and limitations of scientific activity (e.g. investigations on various physiological processes and ecosystems).

Students should learn	Students should be able to
a. Essential life processes in plants	
Nutrition in plants • Plants as autotrophs • Photosynthesis • Need for minerals • Absorption of water and minerals Gas exchange in plants • Occurrence of gas exchange in different parts of plant • Gas exchange in leaves Transpiration • Process and significance • Factors (humidity, light intensity and wind) affecting the rate of transpiration	• Appreciate the significance of plants as autotrophs. • Explain the need for minerals in plants. • Relate the structure of roots to their functions in water absorption. • Relate the features of leaves to gas exchange and prevention of water loss. • Explain the effects of light intensity on gas exchange in plants. • Make connections between transpiration, absorption and transport of water, and cooling of plant. • Explain the effects of environmental factors on the rate of transpiration.
Transport of substances in plants • Transport of water and minerals • Translocation of organic nutrients Support in plants • Cell turgidity • Physical nature of xylem	• Describe the path of materials transport in flowering plants. • Compare the means of support in herbaceous and woody dicotyledonous plants.
b. Essential life processes in animals	
Nutrition in humans • Humans as heterotrophs • Food requirements and functions of different food substances – Carbohydrates – Lipids – Proteins – Vitamins – Minerals (e.g. calcium and iron) – Dietary fibre	• Explain the effect of age, activity and pregnancy on dietary requirements. • Relate health problems to improper diet. • Explain the significance of mechanical and chemical digestion. • Understand the digestion and absorption processes in various parts of the alimentary canal. • Illustrate the adaptive features of the small intestine for food absorption.

Students should learn	Students should be able to
• Balanced diet • Ingestion – Dentition – Mastication • Digestion – General plan of the digestive system – Digestion of carbohydrates, proteins and lipids in various parts of the alimentary canal • Absorption and assimilation – Structural adaptation of small intestine for food absorption – Role of liver – Fate of absorbed food • Egestion	• Describe the routes of the transport of absorbed food and their fates in cells and tissues.
Gas Exchange in humans • General plan of the breathing system • Gas exchange in air sacs • Routes of transport of respiratory gases • Mechanism of ventilation	• Understand the exchange of respiratory gases between the body cells and the external environment. • Relate the structure of various parts of the breathing system to gas exchange.
Transport of substances in humans • General plan of the circulatory system and lymphatic system • Composition and functions of blood, tissue fluid and lymph • Exchange of materials between blood and body cells • Formation of tissue fluid	• Relate the structure of various components of the circulatory system and lymphatic system to transport. • Describe the exchange of materials and the formation of tissue fluid.
c. Reproduction, growth and development	
Reproduction in humans • General plan of the male and female reproductive systems • Structure of sperm and ovum	• Relate the structure of various parts of the reproductive systems to their functions. • Recognise the roles of sperm and ovum in sexual reproduction.

Students should learn	Students should be able to
• Menstrual cycle – Cyclic changes in uterine lining – Ovulation • Fertilisation • Development of embryo and foetus – Placenta – Identical twins and fraternal twins • Birth process • Parental care • Birth control	• Describe the transfer of semen during sexual intercourse and the process of fertilisation. • Relate the structure of the placenta to its role in the development of foetus. • Recognise the significance of parental care and the advantages of breast-feeding. • Understand the biological basis of various methods of birth control.
d. Coordination and response	
Stimuli, receptors and responses • Light as stimulus: the human eye – Major parts of the eye – Rod cells and cone cells – Colour vision – Eye accommodation – Eye defects (long sight, short sight and colour blindness) • Light as stimulus: phototropic response in plants – Responses of root and shoot – Role of auxins • Sound as stimulus: the human ear – Major parts of the ear	• Understand the roles of sense organs and receptors in detecting changes in the environment. • Relate the structure of major parts of the eye to vision. • Explain the causes of eye defects. • Describe how long sight and short sight are corrected with glasses. • Be aware of the surgical methods for eyesight correction. • Recognise the significance of phototropism. • Understand the mechanism of phototropic responses in root and shoot. • Relate the structure of major parts of the ear to hearing.
Nervous coordination in humans • General plan of the nervous system • Central nervous system – Functions of main parts of the brain: cerebrum, cerebellum and medulla oblongata	• Recognise the role of the central nervous system. • Distinguish different types of neurones in terms of structure and function. • Describe the transmission of nerve impulses across a synapse.

Students should learn	Students should be able to
– Functions of spinal cord – Neurone: sensory neurone, interneurone and motor neurone – Synapse • Reflex arc and reflex action • Voluntary actions	• Compare the nature of reflexes and voluntary actions with examples.
Hormonal coordination in humans • Nature of hormonal coordination • General plan of the endocrine system	• Understand the nature of hormonal coordination. • Use an example to illustrate hormone mediated response. • Compare hormonal and nervous coordination.
e. Homeostasis Concept of homeostasis • Importance of homeostasis • Feedback mechanism Parameters of the internal environment • Glucose level and gas content in blood, water content and body temperature Regulation of blood glucose level • Roles of liver, pancreas, insulin and glucagon	• Explain the principle of feedback mechanism with reference to the regulation of blood glucose level. • Appreciate that the internal environment of human body is maintained by the nervous system and the endocrine system.
f. Ecosystems Levels of organisation • Species, population, community, ecosystem, biome and biosphere Major ecosystem types • Freshwater stream, rocky shore, mangrove, grassland and woodland	• Be aware that organisms and their environment are studied at different levels of organisation. • Appreciate the existence of a variety of ecosystems in the local environment.

Students should learn	Students should be able to
Components of an ecosystem • Abiotic factors • Biotic community – Niche and habitat – Species diversity and dominant species – Relationships between organisms ▪ predation, competition, commensalism, mutualism and parasitism – Ecological succession ▪ Primary and secondary succession ▪ Climax community Functioning of ecosystem • Energy flow – Source of energy – Energy flow between different trophic levels – Feeding relationships of organisms • Materials cycling – Carbon cycle • Roles of producers, consumers and decomposers in energy flow and materials cycling	• Identify the abiotic factors of a habitat and explain their effects. • Describe the different types of relationships between organisms in a habitat. • Outline the process of ecological succession. • Use food chains, food webs, pyramids of numbers and biomass to represent the feeding relationships of organisms and energy flow between different trophic levels. • Understand the efficiency of energy transfer in an ecosystem. • Understand the cycling of materials in an ecosystem. • Be aware of the interactions between the biotic community and the abiotic factors of an ecosystem.
Conservation of ecosystem • Impacts of human activities	• Recognise the need for conservation.
Study of a local habitat • Distribution and abundance of organisms – Sampling methods ▪ Quadrats ▪ Line and belt transects • Measurement of abiotic factors (e.g. light intensity, pH, wind, temperature, oxygen, humidity and salinity)	• Conduct and report an ecological study of a local habitat.

Suggested Learning and Teaching Activities

a. Essential life processes in plants

- Design and perform investigations to study the effects of different minerals on plant growth using potted plants; to study the effects of light intensity on gas exchange in land or water plants using hydrogencarbonate indicator solution or data loggers; to compare the distribution of stomata on both sides of a leaf; and to study the effects of environmental factors on the rate of transpiration using potometer.
- Examine the cross sections of the leaf, stem and root of a young dicotyledonous plant using temporary mounts or prepared slides; and the structure of the root of young seedlings using live specimens or prepared slides.
- Perform practical work to demonstrate the occurrence of transpiration; and to trace the uptake of water in herbaceous plant using eosin solution.

b. Essential life processes in animals

- Perform practical work to identify composition in some common foodstuffs; to demonstrate the effect of bile salt on oil; to simulate digestion and absorption in the alimentary canal using dialysis tubing; and to compare the differences in composition between inhaled and exhaled air.
- Design and perform investigations to compare the amount of vitamin C in different fruits and vegetables; and to study the action of digestive enzymes (e.g. amylase on starch-agar plate, protease on milk-agar plate or egg white).
- Examine the alimentary canal and its associated glands, and the breathing system of a dissected mammal or a human torso.
- Examine a pig’s lungs; and the capillary flow in a fish’s tail fin or frog’s web.
- Examine the structure of air sacs, arteries and veins, and the components of blood using prepared slides or photomicrographs.
- Perform dissection of a pig’s heart and examine its structures.

c. Reproduction, growth and development

- Examine photomicrographs, video clips or live cell images of sperms and ova.
- Use audiovisual materials to study the process of fertilisation.
- Examine the male and female reproductive systems of dissected mammals or a human torso.
- Examine photos or video clips taken by ultrasound showing different stages of foetal development.
- Search for information on the effectiveness and possible side effects of various birth control methods; *in vitro* fertilisation and termination of pregnancy.

- Discuss the harmful effects of drinking and smoking habits of a pregnant woman on the development of the foetus.

d. Coordination and response

- Perform dissection of an ox’s eye and examine its structures.
- Search for information on how modern technology helps in rectifying eye defects (e.g. short/long sight, astigmatism, cataract or glaucoma).
- Examine models of the human brain, eye and ear.
- Design and perform investigations on the phototropic responses of roots and shoots.

e. Homeostasis

- Construct a flow chart to illustrate the feedback mechanism.
- Search for information about the physiological consequences of hormonal imbalance, (e.g. insulin) and the remedies, especially through modern advances in science and technology.

f. Ecosystems

- Visit nature reserves, country parks, marine parks, field study centres and other local habitats.
- Construct and interpret food chains, food webs, and pyramids of numbers and biomass.
- Use live or audiovisual materials to show the relationships of organisms in an ecosystem.
- Conduct an ecological study of a local habitat (e.g. freshwater stream and rocky shore).

IV Health and Diseases

Overview

Students will acquire knowledge and develop an understanding of what constitutes health; so that they can make informed decision on the choice of lifestyles, habits, and disease prevention measures. This is designed to help students develop a positive attitude towards health and be aware of both individual and public responsibility for the maintenance of a healthy community. The concept of disease and the routes of pathogen transmission will also be studied.

Scientific Inquiry

This should enable students to:

- make careful observations and accurate records (e.g. examine prepared slides or photomicrographs of pathogens and make biological drawings);
- identify questions and carry out appropriate studies to understand various infectious diseases in our society; and
- classify, collate and display both first and second hand data (e.g. collect information related to health and diseases from the Hospital Authority, Department of Health or the Internet).

STSE Connections

This should enable students to:

- be aware of the application of biological knowledge in maintaining a healthy community and its social, ethical, economic and environmental implications; and

Nature and History of Biology

This should enable students to:

- be aware of the dynamic nature of biological knowledge related to diseases, and understand that science is a human endeavour; and
- understand the nature and limitations of scientific activity (e.g. the causes and transmission of some diseases are not yet known).

Students should learn	Students should be able to
a. Personal health	
Meaning of health	• Recognise the meaning of health.
b. Diseases	
Types of diseases • Infectious diseases • Non-infectious diseases	• Understand the concept of disease. • Distinguish between infectious and non-infectious diseases. • Understand how infectious diseases are transmitted.
Infectious diseases (e.g. cholera, dengue fever, hepatitis B, influenza and tuberculosis) • Causes • Ways of transmission – Water, air, droplets, food, body fluids, vector and direct contact	

Suggested Learning and Teaching Activities

b. Diseases

- Examine photomicrographs, prepared slides or live cell images of some pathogens (e.g. viruses, bacteria, fungi and protists).
- Conduct a project on infectious diseases (e.g. cholera, dengue fever, hepatitis B, influenza and tuberculosis) with reference to their ways of transmission and symptoms.
- Search for information on the major outbreaks of infectious diseases in Hong Kong.

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 context of their school, in accordance with the central framework provided by in Chapter 2.

3.1 Guiding Principles

The following principles can be used as a reference for planning the school-based senior secondary science curricula:

- address the different needs and interests, abilities and learning styles of students;
- facilitate a seamless continuity with the junior secondary science curriculum through a comprehensive coverage of the learning targets to promote integrative use of skills and a balanced development of learning experiences*;
- plan and devise appropriate and purposeful learning and teaching materials, practical work, scientific investigations and projects to develop students' knowledge and understanding, skills and processes, values and attitudes, problem-solving skills, critical thinking skills, creativity, and strategies for learning how to learn;
- set and work on clear and manageable curriculum goals to develop a progressive and appropriate curriculum that serves to bring about pleasurable, meaningful and productive learning experiences; and
- review and plan the curriculum flexibly, and make appropriate adjustments when necessary, taking into account the SBA implementation arrangements as specified in Chapter 5.

3.2 Progression

To cater for students who have a particular interest in learning science and those intending to take two science subjects in science education, it is suggested that schools offer a broad and balanced science curriculum for students in S4, including selected topics from Biology, Chemistry and Physics.

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*The *C&A Guides of Biology, Chemistry and Physics* provide detailed explanation on the interfacing of the curriculum with the junior secondary science curriculum on specific topics.

By studying topics in the three sciences during S4, students will gain an understanding of the different nature and requirements of the three disciplines, and so will be more able to identify their interests and strengths when choosing their specialised study in higher forms.

Figure 3.1 presents the possible pathways and choices offered by schools for students who wish to take two elective subjects in the Science Education KLA.

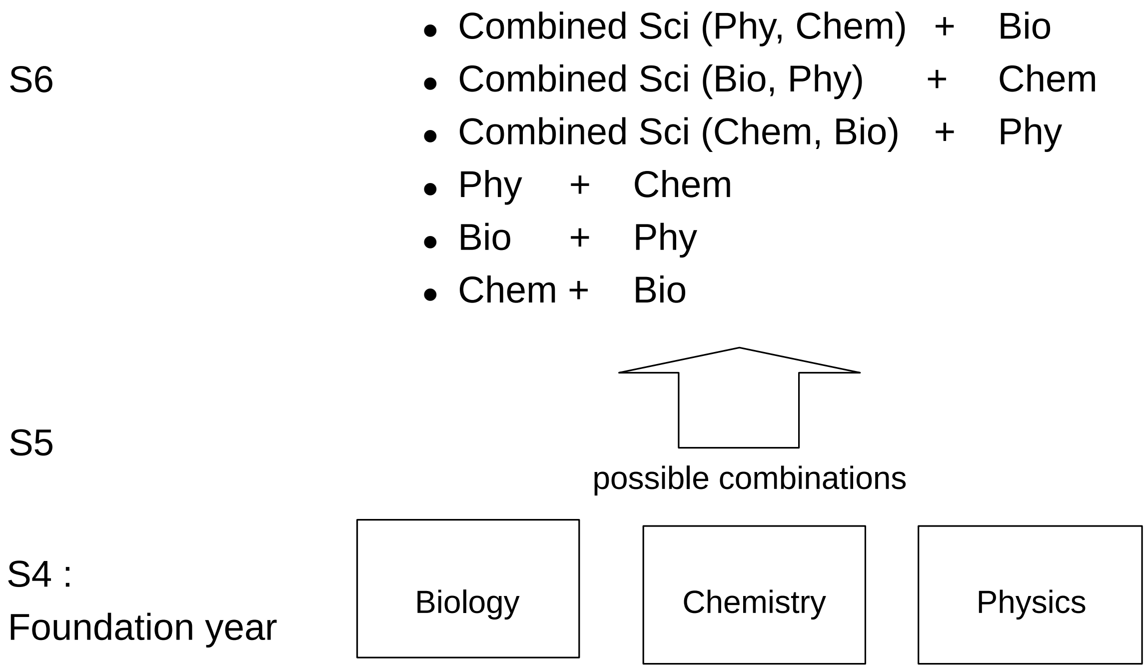

Figure 3.1 Progression of Study in Science Subjects

The following tables present the selected topics recommended for students to study in S4:

Part 1 : Physics	
1. Heat	• Temperature, heat and internal energy • Transfer processes • Change of state
2. Force and Motion	• Position and movement • Force and motion • Work, energy and power
3. Wave Motion	• Nature and properties of waves • Light
Scientific Investigations	

Part 2: Chemistry	
1. Planet Earth	• The atmosphere • The ocean • Rocks and minerals
2. Microscopic World	• Atomic structure • The Periodic Table • Metallic bonding • Ionic and covalent bond • Structures and properties of giant ionic, giant covalent, simple molecular and metallic substances
3. Metals	• Occurrence and extraction of metals • Reactivity of metals • Reacting masses • Corrosion of metals and their protection
4. Acids and Bases	• Introduction to acids and alkalis • Indicators and pH • Strength of acids and alkalis • Salts and neutralisation
5. Fossil Fuels and Carbon Compounds	• Hydrocarbons from fossil fuels • Homologous series, structural formulae and naming of carbon compounds • Alkanes and alkenes

Part 3: Biology	
1. Cells and Molecules of Life	• Molecules of life • Cellular organisation • Movement of substances across membrane • Cell cycle and division • Cellular energetics
2. Organisms and Environment	• Essential life processes in plants • Essential life processes in animals
Scientific Investigations	

<u>The detailed curricula for Biology, Chemistry and Physics parts are listed under the separate subjects.</u>

3.3 Curriculum Planning Strategies

3.3.1 Suggested Learning and Teaching Sequence

In S4, schools are encouraged to offer topics from all three sciences, using a flexible time-tabling arrangement. They may offer these in parallel with an equal number of teaching hours in each week/cycle (e.g. 1.5-2 hours/week) given to each science, or deliver the topics selected in each science sequentially as in the following figures.

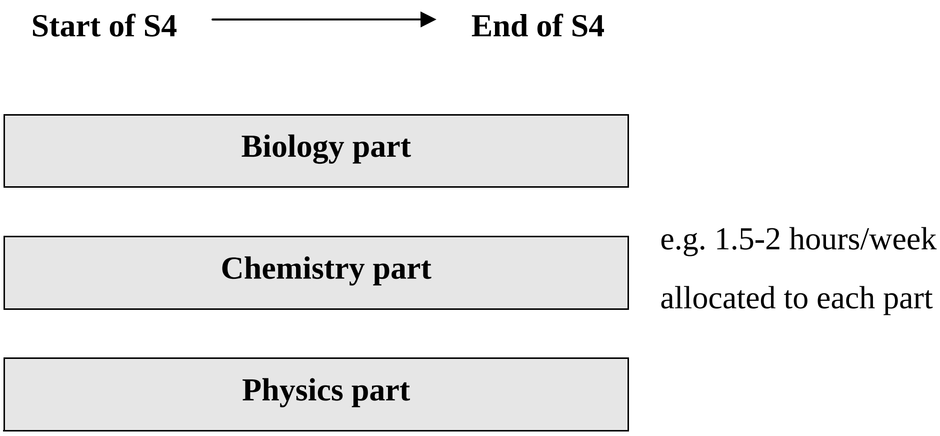

Figure 3.2 Parallel Time-tabling Arrangement

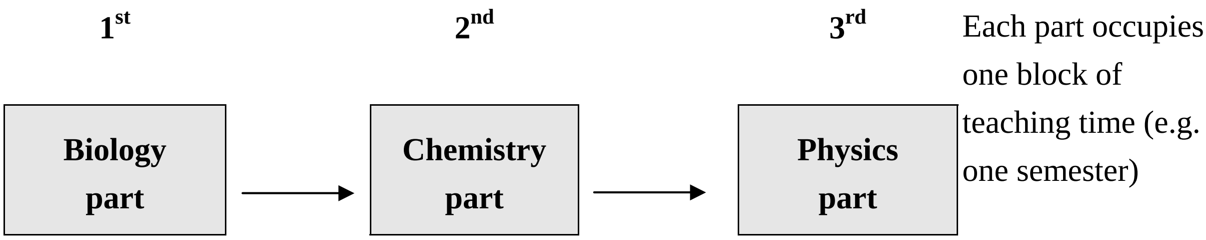

Figure 3.3 Sequential Time-tabling Arrangement

As the topics are not organised strictly in sequential order, teachers may teach the three parts in an interwoven manner in order to highlight the interrelationship of the three science disciplines. The different arrangements have strengths and limitations and, when making a decision, teachers need to take into account how best to use teachers' expertise, the availability of facilities and students' interests.

The *C&A Guides of Biology, Chemistry and Physics* provide further information on curriculum planning strategies. There are some suggested learning and teaching sequences and linkages of the major concepts of individual topics for teachers' reference.

3.3.2 Coordination between the Teaching of Biology, Chemistry and Physics parts

The descriptions above outline how various topics in the three sciences can be delivered in a sequential order. However the teachers concerned need to cooperate effectively to ensure coherence across these three parts. Teachers should demonstrate and provide opportunities for students to understand how science concepts and skills are associated across various topics and how they can be applied in different disciplines. For example, the knowledge of atomic and molecular structure acquired from the Chemistry Part may enhance students' understanding of concepts in *Molecules of life* and *Molecular genetics* in the Biology Part. When the curricula for related topics are planned in a coherent manner, students will show greater interest, progress more smoothly and learn more effectively. It is suggested that teachers assign suitable projects or investigative studies to encourage the interdisciplinary learning of science.

3.3.3 Curriculum Adaptations for Learner Diversity

Students vary greatly in their interests, academic readiness, aspirations and learning styles. In order to help all of them to achieve the learning targets of the curriculum, teachers may vary the organisation of the learning elements in the curriculum framework and use lesson time flexibly. They should also adopt learning, teaching and assessment strategies which connect what has to be learnt to life experience, and provide continuous feedback. Outlined below are some suggestions for teachers to consider in devising a plan for school-based curriculum development to cater for student diversity.

- Varying the sequence of learning and teaching to cater for students with different interests and abilities.
- Setting more challenging learning targets for students with a strong interest or outstanding ability in science and providing them with opportunities to develop their full potential.
- Adapting the depth of treatment to an appropriate level for the topics which are considered to be cognitively more demanding, and providing extra support to help students to master them.

3.4 Curriculum Management

3.4.1 Effective Curriculum Management

In order to develop and manage the curriculum effectively, curriculum leaders in a school have to work collaboratively and take the following aspects into consideration.

(1) Understanding the curriculum and student needs

The curriculum framework for Combined Science outlines the rationale, curriculum aims, learning targets, curriculum structure and organisation, curriculum planning, learning and teaching as well as assessment. A good understanding of the curriculum, the needs and interests of students, and the strengths and culture of the school will facilitate effective school-based curriculum development. School-based curriculum developers should align learning and teaching with the school vision and mission as well as with the central curriculum framework.

(2) Organisation and structure

Curriculum leaders, including Science Education KLA coordinator, science panel chairpersons and science teachers, have to work collaboratively as a team and play different roles in managing the school-based curriculum development. In addition to overseeing and coordinating the implementation of the curriculum, the Science Education KLA coordinator and panel chairpersons have to develop a plan for enhancing teamwork and the professional capacity of teachers.

(3) Curriculum planning

Schools have to develop a plan for school-based curriculum development in science education which ensures coherence among the different science subjects and with other subjects. It is important to ensure progression from the junior secondary science curriculum and provide a balanced foundation in science education for students. Details about curriculum planning strategies are described in Section 3.3 of this chapter.

(4) Capacity building and professional development

Team building can be enhanced through regular exchange of ideas, experiences and reflections, obtained through collaborative lesson preparation, peer coaching and lesson observation. Such practices will help promote a collaborative and sharing culture among teachers, as well as enhancing their professional development. Schools should also provide more time for teachers to participate in various professional development programmes and deploy them appropriately and flexibly in accordance with their strengths.

(5) Resource development

Learning and teaching resources will be developed by the EDB to support the implementation of the curriculum. Schools are encouraged to adapt these resources or to develop their own learning and teaching materials to meet the needs of their students. These materials can be shared among teachers through the development of a school-based learning and teaching resources bank or a sharing platform in the school Intranet. Details about learning and teaching resources are described in Chapter 6.

(6) Managing change

In view of the dynamic nature of scientific knowledge and the changes in contemporary society, school-based curricula need to be flexible. While schools can define the scope and direction of curriculum development with a degree of certainty, their implementation needs to be flexible enough to respond to changes. The strategies for managing change include participation and communication, periodic review to monitor progress and the collection of evidence to make informed changes.

3.4.2 Roles of Different Stakeholders in Schools

Curriculum leaders take on different roles in managing curriculum change and these may vary depending on the school context.

(1) Science Teachers

Science teachers can contribute to the development of the school-based science curriculum by working in line with the school policy and assisting panel chairpersons as individuals and in collaboration with other science teachers. They can also play the role of curriculum leaders by initiating innovative curricular changes.

When implementing the school-based science curriculum, teachers should:

- explain clearly to students the overall plan and purpose of the school-based science curriculum;
- foster a motivating learning environment among students and enable them to become self-directed and self-regulated learners;
- take initiatives to try out innovative learning and teaching strategies;
- initiate sharing of ideas, knowledge and experiences to foster peer support and improvement in learning and teaching;
- work collaboratively with laboratory technicians to design appropriate activities and provide a safe environment conducive to learning;

- keep abreast of the latest curriculum development and changes through reading and sharing with other teachers;
- participate actively in professional development courses, workshops and seminars to enhance their professionalism; and
- review the school-based science curriculum from time to time with a view to improving it.

(2) Science Education KLA Coordinator/Science Panel Chairperson

Science Education KLA coordinators/Science panel chairpersons play a significant role in developing, managing and implementing the curriculum. They also act as a "bridge" between the school administrative personnel and other science panel members. In order to enhance the communication and collaboration among different panel members and to coordinate the implementation of the curriculum, they should:

- take the lead in developing a plan for providing a balanced science education to students by making use of the guidelines set out in the *Science Education KLA Curriculum Guide (P1-S3)* (CDC, 2002b) and related *C&A Guides*;
- ensure smooth interface between Key Stages by working closely with different science panels in school-based curriculum development;
- meet regularly with panel members to discuss matters such as curriculum planning, assessment policies, the use of learning and teaching materials, the adoption of learning and teaching strategies, and to review progress and explore curriculum implementation strategies to enhance the effectiveness of learning and teaching;
- promote regular exchange of learning and teaching ideas, experiences and reflections by various means such as peer coaching, lesson observation and collaborative lesson preparation;
- encourage panel members to participate in professional development courses, workshops, seminars and projects;
- ensure efficient provision and use of facilities and resources (e.g. laboratory facilities and equipment, laboratory technicians and IT equipment) to support the implementation of the curriculum; and
- coordinate among science panels and laboratory technicians to ensure that safety and precautionary measures are taken for the conduct of practical work and scientific investigations.

(3) School Head

School heads take the leading role in directing, planning and supporting school-based curriculum development. It is necessary for them to understand the central curriculum framework and be fully aware of contextual factors such as the needs of the students, the strengths of individual staff members, and the organisational culture in their school. They are encouraged to appoint a Science Education KLA coordinator to oversee the development and implementation of the school-based Science curricula. School heads have to work closely with their Deputy Heads or Academic Masters/Mistresses and should:

- understand the full picture and define the scope of curriculum development for the Science Education KLA in alignment with the vision and mission of the school and the direction of whole school curriculum development;
- clarify the implementation roles and responsibilities of middle level curriculum leaders of the Science Education KLA;
- ensure that students are provided with different options in the Science Education KLA to cater for their needs and aspirations, and that they are equipped with a balanced foundation in science;
- deploy school resources (e.g. laboratory technicians and equipments) appropriately to facilitate effective learning and teaching;
- promote a collaborative and sharing culture among teachers by encouraging collaborative lesson preparation and peer lesson observation;
- provide time for teachers to participate in professional development programmes;
- appreciate and commend progress made, and sustain appropriate curriculum initiatives;
- help parents and learners to understand the school’s beliefs, rationale and practices in the implementation of the curriculum, and their roles in facilitating learning; and
- network with other schools to promote professional exchange of information and the sharing of good practices.

Details about the roles of teachers, KLA heads, panel chairpersons and school heads as the key change agents are described in Booklet 9 of the *Senior Secondary Curriculum Guide* (CDC, 2009).

Chapter 4 Learning and Teaching

This chapter provides guidelines for effective learning and teaching of the Combined Science Curriculum. It is to be read in conjunction with Booklet 3 in the *Senior Secondary Curriculum Guide* (CDC, 2009), which provides the basis for the suggestions set out below. Teachers should also refer to Chapter 4 of the *C&A Guides of Biology, Chemistry and Physics* for more specific details and examples on the learning and teaching of the Biology, Chemistry and Physics parts of this curriculum.

4.1 Knowledge and Learning

Learning is viewed as the process of building personal knowledge, and it can take place in a range of different ways, e.g. through direct instruction, inquiry, construction and co-construction. In order to construct knowledge in science, the emphasis should be placed on the understanding of scientific principles and on concepts and their interconnections, rather than on memorising definitions and unrelated facts. It is also essential for students to gain personal experience of scientific inquiry, to see science as a process, and to develop an understanding of its nature and methods.

4.2 Guiding Principles

Key guidelines for effective learning and teaching of the curriculum are listed below. These take into account the recommendations on learning and teaching in Booklet 3 of the *Senior Secondary Curriculum Guide* (CDC, 2009).

(1) Building on strengths

The strengths of both teachers and students in Hong Kong should be acknowledged and treasured. In learning science, most Hong Kong students are strong in memorising content knowledge, analysing numerical data and understanding scientific concepts.

(2) Prior knowledge and experiences

Learning and teaching activities should be planned with due consideration to students' prior knowledge and experiences.

(3) Understanding learning targets

Learning and teaching activities should be designed and deployed in such a way that the learning targets are clear to both the teacher and the students.

(4) Teaching for understanding

Learning and teaching activities should aim at enabling students to understand, and then act and think flexibly with what they know.

(5) A wide range of learning and teaching activities

A variety of learning and teaching activities should be adopted.

(6) Promoting independent learning

Learning and teaching activities that aim at nurturing generic skills and thinking skills should be used in appropriate learning contexts in the curriculum to enhance students' capacity for independent learning. Students should be provided with opportunities to take responsibility for their own learning.

(7) Motivation

Effective learning takes place best when students are motivated. Various motivation strategies should be used to arouse and sustain students' interest in learning.

(8) Engagement

Learning and teaching activities should aim to engage all students' minds actively in the learning process, so that they remain "on task" and focused.

(9) Feedback and assessment

Providing immediate and useful feedback to students should be an integral part of learning and teaching.

(10) Resources

A variety of resources should be employed flexibly as tools for learning. Suggestions on resources which can be used to enhance learning are outlined in Chapter 6.

(11) Catering for learner diversity

Students have different characteristics. A wide range of learning and teaching strategies should be employed to cater for learner diversity.

4.3 Approaches and Strategies

4.3.1 Approaches to Learning and Teaching

Broadly speaking, there are three common and intertwined pedagogical approaches to learning and teaching science.

(1) "Teaching as direct instruction" involves the transmission of information or modeling of behaviour from teacher to students. This teaching approach includes three key methods: presenting content systematically, providing adequate guidance to students, and assessing students' understanding through questioning, assignments or tests.

(2) "Teaching as inquiry" places the emphasis on the student who must take a personal effort to find out information and then work on it to turn it into knowledge. The approach advocates the use of learning activities such as problem-solving activities, which help students to develop various cognitive abilities, and scientific investigations, which involve the processes of formulating and testing hypotheses, designing appropriate methods, collecting and analysing data, and drawing conclusions. As scientific investigation is one of the strands of Science Education, teachers are encouraged to incorporate scientific investigations into the learning and teaching of the subject where appropriate. Examples of investigations on individual topics are provided in Chapter 2 for teachers' reference.

(3) "Teaching as co-construction" means that learners learn together in a group through dialogue among the students, and between students and teachers. Co-construction of knowledge can be encouraged in a variety of ways, such as by asking open-ended questions, by posing contradictions and inviting responses, by engaging students in discussion and debate and by setting collaborative group work. For instance, STSE connections may be more effectively explored through co-construction because the experiences of both the teacher and the students form a useful resource bank on which to draw.

These three learning and teaching approaches outlined above can be viewed as a continuum along which the role of the teacher varies. Teachers should adopt a variety of approaches and strategies to meet the specific learning targets and outcomes of individual lessons, as well as the varied needs and learning styles of their students. Teachers should also note that a learning target may be attained by using more than one type of strategy and that students can achieve more than one learning target during the same learning process. A range of learning and teaching activities commonly used in science classrooms is listed in Figure 4.1.

Direct instruction	Interactive teaching	Individualisation	Inquiry	Co-construction
• Demonstration • Explanation • Video show	• Questioning • Visits • Using IT and multimedia packages • Whole-class discussion	• Constructing concept maps • Information searching • Reading • Writing learning journals/ note-taking	• Practical work • Problem-solving • Scientific investigations • Simulation and modelling	• Debates • Discussion forums • Group discussion • Project work • Role-play

Figure 4.1 Learning and Teaching Activities in Science

4.3.2 Variety and Flexibility in Learning and Teaching Activities

This curriculum has an in-built flexibility to cater for the varied interests, abilities and needs of students. The flexibility in the design of learning targets and outcomes serves as a way for teachers to strike a balance between the diverse needs of students, and the breadth and depth of the content. Teachers should adopt appropriate learning and teaching approaches and engage students in a variety of learning activities to help them attain the learning targets. Learning and teaching activities such as questioning, reading, discussions, model-making, demonstrations, practical work, field studies, investigations, oral reporting, assignments, debates, information search and role-play should be chosen carefully to construct meaningful learning processes for students.

4.3.3 From Curriculum to Pedagogy: How to start

Pedagogical activities should be made relevant to students' daily lives as far as possible, so that they experience science as interesting and relevant to their daily lives. When evaluating the appropriateness of a pedagogical activity, teachers are advised to refer to the guiding principles listed in Section 4.2. In addition, they should ensure safety in all practical work and scientific investigations in collaboration with laboratory supporting staff.

Apart from the common examples of learning and teaching activities for science listed in Figure 4.1, further details and examples of suggested learning and teaching strategies for the Biology, Chemistry and Physics parts are listed in their respective *C&A Guides*.

4.4 Interaction

Interaction involves conversation between teachers and students and between students and students, and is an integral part of many learning and teaching strategies. Through interaction students can explore what they know and do not know and clear up their confusions, and teachers can ensure that their explanations are well understood.

4.4.1 Scaffolding Learning

Teachers have to scaffold students' learning to help them overcome any hurdles they may face. Scaffolding learning involves purposeful interaction between teacher and students, in which the teacher facilitates learning by providing appropriate guidance and tools. Scaffolding may take many forms, such as:

- a collection of resource materials – for example, an article on a science topic with good descriptions and schematic drawings to help students understand the topic;
- a learning task with clear procedural guidelines and templates – for instance, a worksheet with well-structured questions to guide students in planning for their own experiments;
- guidance, in a variety of formats – for example, showing a video clip or presenting a demonstration to enhance the acquisition of practical skills in science;
- teacher debriefings – for instance, the presentation of a clear conceptual framework at the end of a learning and teaching activity when students have difficulties in "distilling" the essence of the activity, or encounter obstacles that significantly hinder their learning.

The effective use of scaffolds helps students to make sense of concepts and build knowledge individually or collaboratively. Scaffolding helps students to keep up their momentum in learning. In order to develop students' capacity for independent learning, it is important that scaffolds should be removed gradually in accordance with their progress in learning.

4.4.2 The Use of Effective Questioning

To be effective, different types of questions should be used in different contexts. For example, closed questions which have predetermined correct answers are concerned with recalling factual knowledge or reporting simple information. They are useful for quick checks on students' background knowledge. On the other hand, open-ended questions that encourage thinking enable teachers to elicit students' understanding and their ideas, and can trigger divergent thinking. This is because open-ended questions allow for a range of responses and require students to think critically about information, ideas and opinions, as well as to think in creative and evaluative ways. Teachers need to exercise patience and give suitable “wait-time” for students to process questions and formulate their answers.

4.4.3 The Use of Feedback

Teachers should provide the sort of feedback to students that encourages them and enables them to reflect on their learning and improve it. Students can also receive useful feedback from their peers and others (e.g. laboratory supporting staff). Feedback from students enables teachers to adjust their pedagogy to enhance learning effectiveness. Effective feedback goes beyond the simple provision of marks, and involves, for example, oral or written teacher comments on students’ strengths and weaknesses in learning, or suggestions on areas for improvement. Figure 4.2 outlines the use of feedback to enhance independent learning in students.

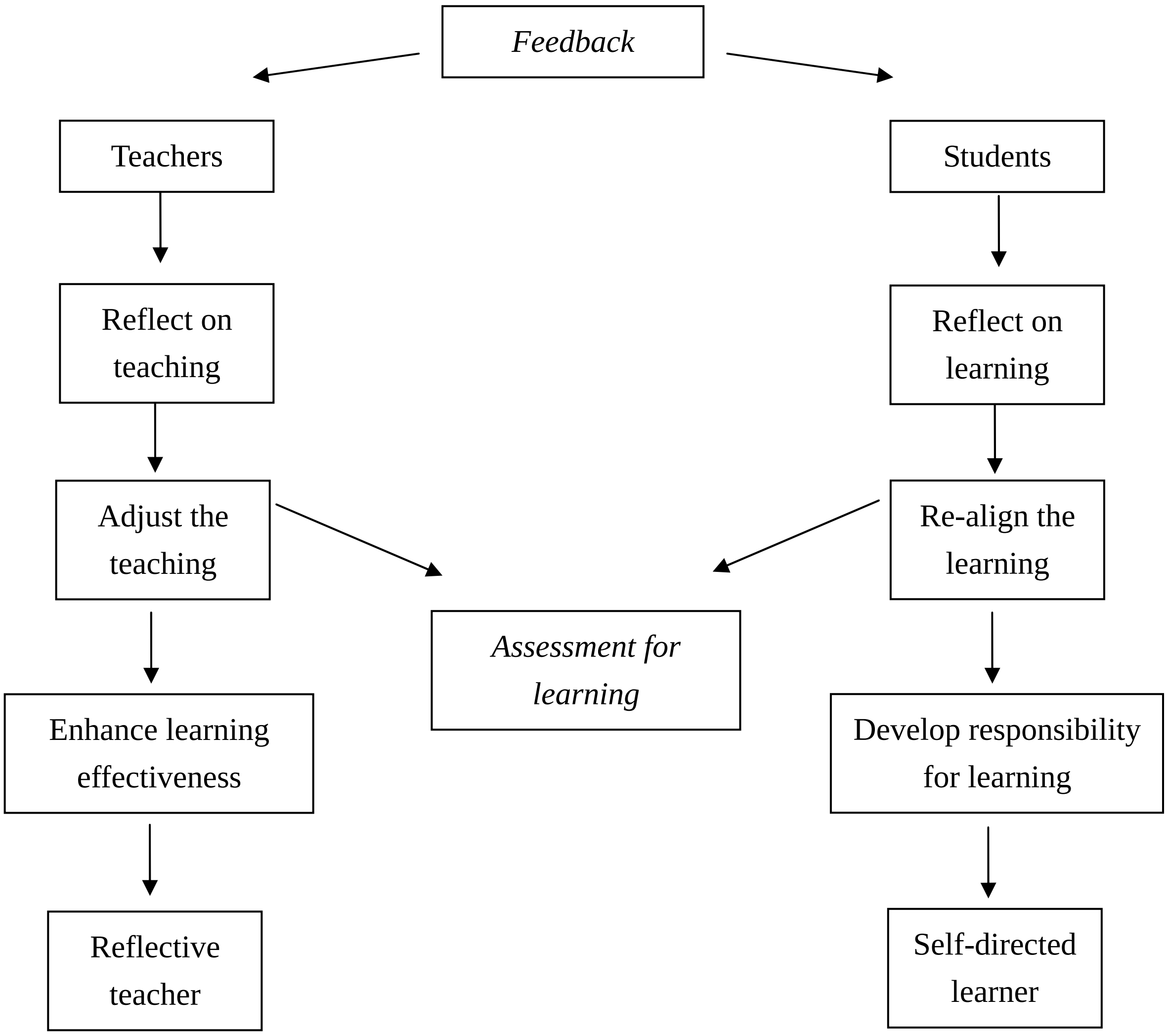

Figure 4.2 The Use of Feedback

4.5 Catering for Learner Diversity

Learner diversity exists in every classroom and should be taken into account when planning learning and teaching strategies. It is unrealistic to expect every student to achieve the same level of attainment. Diverse learning and teaching strategies should be adopted to give students opportunities to learn in different ways to realise their potential. In this regard, teachers are encouraged to find out more about their students' interests, abilities, strengths and needs through investigating their general background, personal contacts with other students, and progress in learning. This will enable teachers to make informed decisions on the most appropriate strategies.

4.5.1 Strategies to Cater for Learner Diversity

Suggestions on curriculum planning to cater for learner diversity are outlined in Section 3.3.3 of Chapter 3. Teachers may consider the following suggestions in designing their learning and teaching strategies.

(1) Employing a variety of learning and teaching activities to address students' different learning styles

Some students are visual learners; some are auditory learners; and some are kinaesthetic learners. Teachers have to adopt a range of presentation modes and vary their pedagogical strategies to address such differences. A variety of resources including textual, visual and audio materials may be used; and a variety of individual and group work should also be arranged to allow students to study and learn in their preferred style.

(2) Adjusting the learning tasks for students with different abilities

The basic idea is to vary the scale, nature and demand of learning tasks for students of differing abilities. For capable students, teachers have to design tasks which are challenging enough to maintain their motivation. With students who are less able, small and less demanding tasks help them to build up their confidence gradually and to learn effectively. For example, for less able students, the teacher may break down a complicated investigation into a series of simple ones. However, for capable students, scientific investigations can be made more demanding by encouraging a higher level of thinking, including more variables, requiring the collection of more data, or imposing the use of more sophisticated instrumentation and skills.

(3) Identifying and providing manageable "building blocks" for different ability groups of students

Teachers must identify the "building blocks" of learning and systematically make them available to students in manageable chunks that do not exceed their capacity, as this will enable them to learn more efficiently and enhance their overall capacity for self-directed learning.

(4) Varying the degree and nature of teacher intervention

Students vary in the amount and type of support, guidance and challenge needed for them to achieve the learning targets of the curriculum. Teachers should be sensitive enough to offer support to slow starters, to provide extra guidance to less able students, and to add further challenges for more able students. They should also consider whether extra support and scaffolding have to be provided for some students for the more demanding topics. As the performance of such slow starters improves, teachers should gradually reduce the extent to which they intervene in the learning process, to allow them to learn more independently.

(5) Flexible grouping

Student diversity can be viewed as an opportunity to get students to provide mutual support, particularly when they work collaboratively to complete learning tasks. Students of differing abilities can be grouped together so that the more able ones can share their knowledge with the less able ones. Alternatively, teachers can group together students of similar ability to work on tasks with an appropriate degree of challenge.

4.5.2 Information Technology as a Learning Tool to Cater for Learner Diversity

Used appropriately, information technology (IT) can be very effective in catering for different learning styles and expanding students' learning beyond the classroom. Students who are quiet in class may participate actively and contribute useful ideas in an online discussion forum. Online assessment tools, with mechanisms to support learning, can also be used to motivate students and promote "assessment *for* learning". The multimedia and interactive elements in IT are particularly useful for students who prefer visual or auditory approaches to learning. Besides, web-based learning resources can enable students to learn at their own pace and follow up their own interests. Students are encouraged to establish a learning community with their teachers and classmates by using IT tools such as e-mail, web-based instant messages and bulletin boards.

4.5.3 Catering for Gifted Students

Students with a very strong interest or talent in science need to be helped to fulfill their full potential. One way of achieving this is through acceleration – that is, by allowing gifted students to move quickly through particular courses (e.g. the Physics Olympiad programme), while keeping them with their peers for most classes. Another approach is through enrichment which provides gifted students with additional challenging or more thought-provoking work, while again keeping them with their peers in school. Such students should be given more challenging scientific inquiry activities. For example, in conducting scientific investigations, teachers should not only design more complex tasks for them, but also allow them to choose more challenging tasks to work on. Gifted students can set the objectives for their own investigations, thus allowing them to act independently as learners in various processes, such as defining a problem, using a wide range of information sources and evaluating investigation procedures.

In addition, arrangements can be made for gifted students to participate in a variety of learning programmes (e.g. the Young Scholar Programme for Biology) or science competitions (e.g. Hong Kong Chemistry Olympiad for Secondary Schools, Hong Kong Student Science Project Competition) and research projects which develop their capabilities. In this way, they can explore their own personal interests in the learning of science.

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Chapter 5 Assessment

This chapter discusses the role of assessment in learning and teaching Combined 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 Combined 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* (SSCG) (CDC, 2009).

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.

The 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 Combined Science and the new Applied Learning courses. It needs to be read in conjunction with other information about students given 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 utilizing 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 is something that 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* (CDC, 2009) 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* (CDC, 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 assessments (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 that they benefit from practice and experience with such tasks for formative assessment purposes without penalty, similar tasks will need to be administered subsequently as part of the public assessment process 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, this means 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 needs 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.

Part 1: Physics

The assessments in Physics aim to evaluate students' abilities to:

- recall and show understanding of the facts, concepts, models and principles of physics, and the relationships between different topic areas in the curriculum framework;
- apply knowledge, concepts and principles of physics to explain phenomena and observations, and to solve problems;
- demonstrate understanding of the use of apparatus in performing experiments;
- demonstrate understanding of the methods used in the study of physics;

- present data in various forms, such as tables, graphs, charts, diagrams, and transpose them from one form into another;
- analyse and interpret data, and draw conclusions from them;
- show understanding of the treatment of errors;
- select, organise, and communicate scientific information clearly, precisely and logically;
- show understanding of the applications of physics to daily life and the contributions of physics to the modern world;
- show awareness of the ethical, moral, social, economic and technological implications of physics, and critically evaluate physics-related issues; and
- make decisions based on the examination of evidence using knowledge and principles of physics.

Part 2: Chemistry

The assessments in Chemistry aim to evaluate students' abilities to:

- recall and show understanding of chemical facts, patterns, principles, terminology and conventions;
- demonstrate understanding of the use of apparatus and materials in performing experiments;
- handle materials, manipulate apparatus, carry out experiments safely and make accurate observations;
- demonstrate understanding of the methods used in chemical investigations;
- analyse and interpret data from various sources, and draw relevant conclusions;
- manipulate and translate chemical data and perform calculations;
- apply chemical knowledge to explain observations and solve problems which may involve unfamiliar situations;
- select and organise scientific information from appropriate sources and communicate this information in an appropriate and logical manner;
- understand and evaluate the social, economic, environmental and technological implications of the applications of chemistry; and
- make decisions based on the examination of evidence and arguments.

Part 3: Biology

The assessments in Biology aim to evaluate students' abilities to:

- recall and show understanding of facts, concepts and principles of biology, and the relationships between different topic areas in the curriculum framework;
- apply biological knowledge, concepts and principles to explain phenomena and observations, and to solve problems;
- formulate working hypotheses, and plan and perform tests for them;

- demonstrate practical skills related to the study of biology;
- present data in various forms, such as tables, graphs, charts, drawings, diagrams, and transpose them from one form into another;
- analyse and interpret both numerical and non-numerical data in forms such as continuous prose, diagrams, photographs, charts and graphs – and make logical deductions and inferences and draw appropriate conclusions;
- evaluate evidence and detect errors;
- generate ideas; select, synthesise and communicate ideas and information clearly, precisely and logically;
- demonstrate understanding of the applications of biology to daily life and its contributions to the modern world;
- show awareness of the ethical, moral, social, economic and technological implications of biology, and critically evaluate biology-related issues; and
- make suggestions, choices and judgments about issues affecting the individual, society and the environment.

5.4 Internal Assessment

This section presents the guiding principles that can be used as the basis for designing internal assessment and some common assessment practices for Combined 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 curriculum planning, teaching progression, student abilities and local school contexts. 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.

(1) Alignment with the learning objectives

A range of assessment practices should be used to assess the achievement of different learning objectives for whole-person development. These include knowledge and understanding of scientific principles and concepts, 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 assessment criteria should also be made known to students so that they have a full understanding of what is expected of them.

(2) Catering for the range of student ability

Assessment practices incorporating different levels of difficulty and 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.

(3) 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 own pace of learning, which will have a positive impact on their commitment to learning.

(4) 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. Such feedback helps students to sustain their momentum in learning, and identify their strengths and weaknesses.

(5) 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 assessment tasks that make reference to the school's own context (e.g. its location, relationship with the community, and mission).

(6) Making reference to the 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 student learning.

(7) 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.

(8) 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 such as assignments, practical work and scientific investigations, oral questioning, suited to the Combined Science 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.

(1) Assignment

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 PowerPoint 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.

(2) Practical work and scientific investigation

Practical work and scientific investigation 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 can be improved. Reading students' laboratory reports can provide teachers with a good picture of students' understanding of the scientific concepts and principles involved, as well as their ability to handle and interpret data obtained in investigations.

(3) Oral questioning

Oral questioning can provide teachers with specific information on how 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.

5.5 Public Assessment

5.5.1 Guiding Principles

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

(1) 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 the 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 Combined Science places 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 scientific investigative skills and generic skills.

(2) 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.

(3) Inclusiveness

The assessments and examinations in the HKDSE need to accommodate the full spectrum of student aptitude and ability.

The public examination for Combined Science contains questions testing candidates' knowledge in the three science disciplines – Physics, Chemistry and Biology – and questions testing higher-order thinking skills. At the same time, the SBA component offers room for a wide range of practical activities to cater for the different preferences and readiness among students and/or schools.

(4) Standards-referencing

The reporting system is "standards-referenced", i.e. student performance is matched against standards, which indicate what students have to know and be able to do to merit a certain level of performance. Level descriptors have been developed for Combined Science to provide information about the typical performance of candidates at the different levels.

(5) Informativeness

The HKDSE qualification and the associated assessment and examinations system should provide useful information to all parties. First, it provides feedback to students on their performance and to teachers and schools on the quality of the teaching provided. Second, it communicates 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 the standards. Third, it facilitates selection decisions that are fair and defensible.

The public assessment of Combined Science consists of three parts: Physics, Chemistry and Biology. Candidates should choose any two parts to form the basis of their assessment according to the curriculum they follow. As a result, there are three options available: Combined Science (Physics, Chemistry), Combined Science (Biology, Physics), and Combined Science (Chemistry, Biology).

5.5.2 Part 1: Physics

(1) Assessment design

The table below shows the assessment design of the Physics part with effect from the 2016 HKDSE Examination. The assessment design is subject to continual refinement in the light of feedback from live examinations. Full details are provided in the Regulations and Assessment Frameworks for the year of the examination and other supplementary documents, which are available on the HKEAA website (www.hkeaa.edu.hk/en/hkdse/assessment/assessment_framework/).

Component		Weighting	Duration
Public Examination	Questions set on the Physics part of the curriculum	40%	1 hour 40 minutes
School-based Assessment (SBA)		10%	

(2) Public examinations

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

Various kinds of items, including multiple-choice questions, short questions, structured questions and essays, are used to assess students' performance in a broad range of skills and abilities. Multiple-choice questions permit a more comprehensive coverage of the curriculum, and short questions can be used to test basic knowledge and concepts. In structured questions, candidates have to analyse given information and apply their knowledge to different situations. Finally, essay questions allow candidates to discuss issues in physics in depth and demonstrate their ability to organise and communicate ideas logically and coherently. Schools may refer to the live examination papers regarding the format of the examination and the standards at which the questions are pitched.

(3) 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 Physics is to enhance the validity of the assessment and by including the assessment of students' practical skills 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 Physics, SBA can serve to motivate students by requiring them to engage in meaningful activities; and for teachers, it can reinforce curriculum aims and good teaching practice, and provide structure and significance to an activity they are in any case involved in on a daily basis, namely assessing their own students.

The SBA of Physics covers the assessment of students' performances in practical work in their S5 and S6 years of the course. Candidates are required to perform a stipulated amount of practical work, which may include designing experiments, reporting and interpreting experimental results, etc. The work should be integrated closely with the curriculum and form a part of the normal learning and teaching process.

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 has taken into consideration the wide range of student ability and efforts have been 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 are provided to teachers by the HKEAA.

5.5.3 Part 2: Chemistry

(1) Assessment design

The table below shows the assessment design of the Chemistry part with effect from the 2016 HKDSE Examination. The assessment design is subject to continual refinement in the light of feedback from live examinations. Full details are provided in the Regulations and Assessment Frameworks for the year of the examination and other supplementary documents, which are available on the HKEAA website (www.hkeaa.edu.hk/en/hkdse/assessment/assessment_framework/).

Component		Weighting	Duration
Public Examination	Questions set on the Chemistry part of the curriculum	40%	1 hour 40 minutes
School-based Assessment (SBA)		10%	

(2) Public examination

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

Various types of items, including multiple-choice questions, short questions, structured questions and essays, are used to assess students' performance in a broad range of skills and abilities. Multiple-choice questions permit a more comprehensive coverage of the curriculum, while basic knowledge and concepts can be tested through short questions. Structured questions require candidates to analyse given information and apply their knowledge to different situations. Finally, essay questions allow candidates to discuss chemistry topics in depth and demonstrate their ability to organise and communicate ideas logically and coherently. Schools may refer to the live examination papers regarding the format of the examination and the standards at which the questions are pitched.

(3) 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 Chemistry is to enhance the validity of the assessment by including the assessment of students' practical skills 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 Chemistry, SBA can serve to motivate students by requiring them to engage in meaningful activities; and for teachers, it can reinforce curriculum aims and good teaching practice, and provide structure and significance to an activity they are in any case involved in on a daily basis, namely assessing their own students.

The SBA of Chemistry covers the assessment of students' performances in practical work in their S5 and S6 years of the course. Candidates are required to perform a stipulated amount of practical work, which may include designing experiments, reporting and interpreting experimental results, etc. The work should be integrated closely with the curriculum and form a part of the normal learning and teaching process.

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 has taken into consideration the wide range of student ability and efforts have been 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 are provided to teachers by the HKEAA.

5.5.4 Part 3: Biology

(1) Assessment design

The table below shows the assessment design of the Biology part with effect from the 2016 HKDSE Examination. The assessment design is subject to continual refinement in the light of feedback from live examinations. Full details are provided in the Regulations and Assessment Frameworks for the year of the examination and other supplementary documents, which are available on the HKEAA website (www.hkeaa.edu.hk/en/hkdse/assessment/assessment_framework/)

Component		Weighting	Duration
Public Examination	Questions set on the Biology part of the curriculum	40%	1 hour 40 minutes
School-based Assessment (SBA)		10%	

(2) Public examination

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

Various kinds of items, including multiple-choice questions, short questions, structured questions and essays, are used to assess students' performance in a broad range of skills and abilities. Multiple-choice questions permit a more comprehensive coverage of the curriculum, while basic knowledge and concepts can be tested through short questions. In structured questions, candidates may be required to analyse given information and to apply their knowledge to different situations. Finally, essay questions allow candidates to discuss biological issues in depth and demonstrate their ability to organise and communicate ideas logically and coherently. Schools may refer to the live examination papers regarding the format of the examination and the standards at which the questions are pitched.

(3) 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 Biology is to enhance the validity of the assessment by including the assessment of students' practical skills 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 Biology, SBA can serve to motivate students by requiring them to engage in meaningful activities; and for teachers, it can reinforce curriculum aims and good teaching practice, and provide structure and significance to an activity they are in any case involved in on a daily basis, namely assessing their own students.

The SBA of Biology covers the assessment of students' performance in practical tasks throughout the S5 and S6 school years. Students are required to perform a stipulated number of pieces of practical work/investigations. The practical work/investigations 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 biology in performing these tasks, through which their practical, process and generic skills will be developed and assessed.

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 has taken into consideration the wide range of student ability and efforts have been 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 are provided to teachers by the HKEAA.

5.5.5 Standards and Reporting of Results

Standards-referenced reporting is adopted for the HKDSE. What this means is that candidates' levels of performance are reported with reference to a set of standards as defined by cut scores on the mark 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.

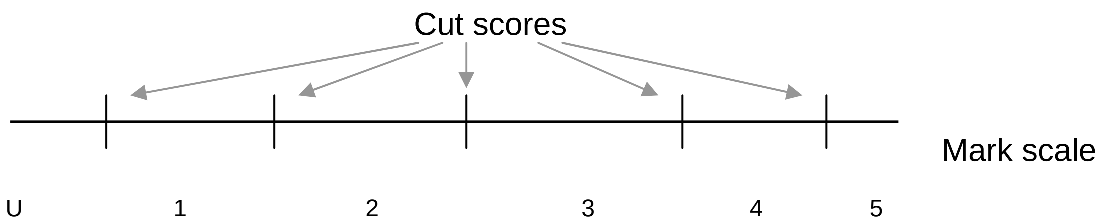


Figure 5.1 Defining Levels of Performance via Cut Scores on the Mark Scale for a given Subject

Within the context of the HKDSE there are five cut scores, which are used to distinguish five levels of performance (1–5), with 5 being the highest. A performance below the cut score for Level 1 is labelled as "Unclassified" (U).

For each of the five levels, a set of written descriptors has been developed to 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 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 are provided to illustrate the standards expected of them. These samples, when used together with the level descriptors, will clarify the standards expected at the various levels of attainment.

In setting standards for the HKDSE, Levels 4 and 5 are set with reference to the standards achieved by students awarded grades of 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 at 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 is made up of results in both the public examination and the SBA. SBA results for Combined Science are statistically moderated to adjust for differences among schools in their marking standards, while preserving the rank ordering of students as determined by the school.

To provide finer discrimination for selection purposes, the Level 5 candidates with the best performance have their results annotated with the symbols ** and the next top group with the symbol *. The HKDSE certificate itself records the level awarded to each candidate.

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. Teachers should also refer to Chapter 6 of the *C&A Guides for Biology, Chemistry and Physics* for more details on the learning and teaching resources specific to the Biology, Chemistry and Physics parts of this curriculum.

6.1 Purpose and Function of Learning and Teaching Resources

Teachers are encouraged to make use of various types of resources in their lessons, and not to confine themselves to using textbooks. Resources on the Internet, for example, not only provide interactive learning opportunities but also widen students' horizons by keeping them abreast of the latest scientific and technological developments.

School-based learning and teaching materials should cater for students' needs. Learning resources that provide students with experiences outside school are also particularly valuable for understanding abstract ideas and concepts, and students may use them for independent learning, with teachers' guidance.

6.2 Guiding Principles

Different learning and teaching resources have to be used to meet the different objectives of individual lessons. The most important principle for the selection of resources is "fitness for purpose".

Learning and teaching resources for science should:

- provide a sense of purpose and direction for learning;
- ensure that students possess the required 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 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 support student-centred learning and help students to construct models, theories and understanding for themselves.

In considering which science textbooks to select, schools should consider:

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

A set of guiding principles has been formulated for the writing, reviewing and selection of quality textbooks. When choosing textbooks, teachers are encouraged to refer to these principles in the textbook information at http://www.edb.gov.hk/textbook.

6.3.2 References

A variety of reference materials can be used to enrich the curriculum, arouse students' interest in learning, and promote "Reading to Learn".

(1) Textual material

Students should be encouraged to read extensively to extend the scope of their knowledge and understanding. There are many useful and interesting texts (e.g. books, journals, magazines) of appropriate breadth and depth. These include, for example, stories about modern science and articles on current developments and issues in science. These enrich the curriculum, arouse students' interest in learning, and promote "Reading to Learn". It is important to set up a text-rich environment with ample curriculum-related materials appropriate to students' ability, linguistic competence and interests to encourage them to get into the habit of reading about science, and so kindle a lifelong interest in it.

(2) Mass media

Materials from the mass media, including audio-visual materials, news articles, TV programmes and advertisements are authentic resources for helping students to learn and make informed decisions and judgments. Videotaped programmes can keep students abreast of the latest scientific and technological developments; and a large number of television programmes have a high educational value. Also, documentaries produced by professional bodies and broadcasting organisations are often pitched at an appropriate level for students. Teachers are encouraged to bring such TV programmes to students' attention as they will find learning more relevant and interesting when using them.

Local newspapers can also provide valuable articles on which to develop learning activities and assessment tasks. To extend their learning, students can collect cuttings on topics of interest to them in relation to science. Learning and teaching resources from the media can provide students with a variety of perspectives on science-related issues and stimulate their thinking. Students' motivation and interest in learning science will also be increased by discussing relevant media reports. Teachers should make flexible use of such resources for consolidating concepts, raising conceptual conflicts, visualising connections, and evaluating and applying scientific knowledge.

Teachers should, however, be aware of the risks associated with the use of such a variety of resources, as some may 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 truth of the information. Resources need to be examined carefully to ensure that they are appropriate for the learning and teaching intentions.

6.3.3 The Internet and Technology

The Internet and technology play an important role in providing learning and teaching resources for science. Strategic use of technology can enhance student engagement and give convenient access to vast amounts of information. Teachers can act as facilitators of learning by helping students to search for information and work on it in order to turn it into knowledge.

The Internet and technology can help students to learn by:

- providing audio-visual aids for understanding difficult concepts;
- providing access to information from a wide range of sources and processing large quantities of information;

- allowing students to work at their own pace, including the use of specially designed software;
- promoting interaction and collaboration among learners, and between the teacher and learners;
- facilitating the acquisition of information, the development of critical thinking, and the co-construction of knowledge.

Teachers are encouraged to make use of the Internet to promote active learning in students, as it offers opportunities for them to collaborate with their peers in other schools, obtain and deal with real live data, discuss with scientists, publish their work and access learning materials and journals. Many Internet sites offer rich sources of information and materials on issues related to science. It is useful for teachers to give students hints, key words or focused areas for Internet searches, to preview and bookmark useful websites, and to make connections to useful websites in their school network.

There are also computer software programmes suitable for learning and teaching science. Such programmes include tutorial software, databases of information and simulations or modelling of processes and experiments. For instance, students may use a computer simulation to perform virtual experiments and test their proposed models, which helps them to develop conceptual understanding and reasoning from their own ideas. Some CD-ROMs provide students with interactive learning experiences by presenting information in a variety of forms and requiring them to make notes, search for key words, answer questions, give explanations or solve problems. Finally, the use of devices such as data loggers and computer-based laboratories can help students to collect, interpret and analyse data when conducting scientific investigations.

6.3.4 Community Resources

Various government departments, non-government agencies and educational institutions can contribute to 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 have been identified and provided in Chapter 6 of the *C&A Guides of Biology, Chemistry and Physics* 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 be a very valuable resource for supporting student learning. Parents and alumni from different professions can be invited to deliver speeches/lectures to enable students to gain authentic knowledge about various disciplines. They can share their views on the value of learning to learn to encourage students to learn.

The EDB will continue to develop and update useful resources, inclusive of supplementary notes, to support the implementation of the curriculum. A list of resource materials published by the EDB can be found in Appendix 2. To assist schools in managing curriculum change, the EDB has provided a curriculum resources directory service at http://www.edb.gov.hk/cr, which provides a central pool of ready-to-use learning and teaching resources and useful references developed by the EDB and other parties.

6.4 Flexible Use of Resources

A wide range of learning and teaching resources should be used flexibly to enhance the effectiveness of learning and teaching and support the implementation of the Combined Science Curriculum. To assist schools in implementing the new curriculum, the EDB will continue to provide them with additional funding and encourage flexibility in the use of resources to cater for their diverse needs. Schools are advised to refer to the relevant circulars issued by the EDB from time to time. Teachers' selection of learning and teaching resources from the various sources outlined above should be based on the needs of their students; and, for this purpose, they may adapt and modify the materials from different sources or develop school-based learning and teaching resources to complement the textbooks when necessary.

6.5 Resource Management

6.5.1 Accessing Useful Resources

Teachers and students should share the responsibility for locating useful learning and teaching resources. Teachers may provide students with lists of recommended websites and references which are specific to the learning of particular topics in science; and students can then follow this up by searching for useful resources from the Internet, libraries, government departments and other community organisations on their own, and they can also make suggestions for enriching the teachers' lists.

6.5.2 Sharing Resources

A culture of sharing is useful for resource and 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; and
- teachers to share their experiences, for example, by using well-established web-based platforms such as the Hong Kong Education City.

6.5.3 Storing Resources

Schools should assign staff to keep up-to-date inventories of learning resources. IT is helpful for managing and storing the materials acquired – for example, the school Intranet can be used to give students and teachers easy access to suitable resources for specific topics and subjects. Software which is commonly available in schools, such as spreadsheets, word processing and database programmes can also be useful tools for this purpose. Keeping systematic records and providing easy access to learning and teaching resources, and to laboratory equipment, can have a significant impact on learning effectiveness.

Science teachers should work closely with teacher-librarians to provide a wide range of reading and learning resources for students. The teacher-librarian, as an information specialist, is in the best position to help students to acquire the information skills and attitudes necessary for using information appropriately and ethically.

Appendix 1

Time-tabling arrangement and the deployment of teachers to cater for the diverse needs of students

There are four subjects, namely Biology, Chemistry, Physics and Science (including Mode I and Mode II) offered in the Science Education KLA, leading to a number of possible subject combinations for students. The various subject combinations are considered worthwhile and valuable to serve the needs of students pursuing different post-secondary pathways. Possible ways of managing school time-tabling and resources to allow students more choices are discussed below.

Implementation of Mode I - Integrated Science Curriculum

If this subject is taken by a class of students as a single elective subject, normal time-tabling can be adopted. It is a common practice in schools that a teacher will take up the teaching of a course for three years. However, due to the interdisciplinary 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 that they are familiar with. This also helps to share out the work required to prepare for this curriculum.

We encourage schools to promote partnership in terms of preparation of lessons, team teaching as well as lesson observations so that teachers work and learn together. It is recommended that schools reserve time for collaborative lesson planning in the time-table.

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 different classes. With special time-tabling, it is then possible to swap the classes so that teachers can concentrate on modules that they are more familiar with. 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 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 for all three levels. The teacher is required to teach beyond his/her own expertise, and so time should be allowed for his/her professional development, knowledge updating and lesson preparation.

Option B: Teachers with different expertise share the teaching of one class. The teachers will be able to concentrate on preparing the modules they are more familiar with.

Option C: Two teachers with different expertise teach two classes, with each teaching one class. There should be regular sharing between the two teachers, helping each other in preparing resources and knowledge enrichment.

Option D: Two teachers with different expertise teach two classes, with a special time-table which allows them to swap their responsibilities at different times during the school year.

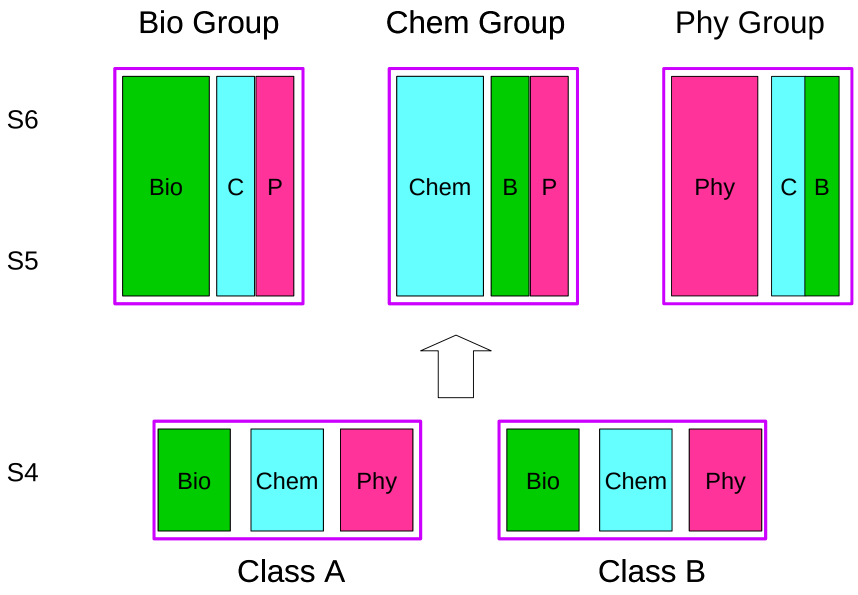
Implementation of Mode II - Combined Science Curriculum with Biology, Chemistry and Physics

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

To help students to build up a broader knowledge base, it is recommended that students 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 study 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 *C&A Guides* for a selection of topics suitable to be included in the S4 curriculum to help students to build a broad-based foundation. Schools may consider the following two arrangements in S5 and S6:

(1) Flexible grouping and split class arrangement

Students from two or three different classes are arranged into three groups namely, Biology group, Chemistry group and 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 periods per cycle for the other two complementary subjects.



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

To facilitate the split class arrangement, three common blocks in the time-table have to be arranged for 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 have chosen to specialise in their subject. In the 2nd and 3rd Blocks, they will be spending two periods each with 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)	Biology part of Combined Science (Chem Group)	Chemistry part of Combined Science (Phy Group)	Physics part of Combined Science (Bio Group)
3rd Block (2 periods)	Biology part of Combined Science (Phy Group)	Chemistry part of Combined Science (Bio Group)	Physics part of Combined Science (Chem Group)

(2) 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**
Core subjects	Chin Lang	Chin Lang	Chin Lang
	Eng Lang	Eng Lang	Eng Lang
	Math	Math	Math
	LS	LS	LS
1st Block	Bio / Combined Sci (Chem, Bio) / X from other KLAs		
2nd Block	Chem / Combined Sci (Phy, Chem) / X from other KLAs		
3rd Block	Phy / Combined Sci (Bio, Phy) / X from other KLAs		

Other Classes
Chin Lang
Eng Lang
Math
LS
Integrated Science
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 course)

From the time-table, it is clear that two teachers of each science discipline are needed. For example, in the third common block, one Physics teacher is needed to teach four periods of Physics and another Physics teacher is needed to teach the two periods for the Physics part of the Combined Science (Bio, Phy) Curriculum.

Appendix 2

Resources published by the Education Bureau

Physics Resources

1. Physics World

   http://www.hk-phy.org
   At *Physics World*, teachers and students will find a rich and growing collection of teaching resources. This website is subdivided into seven main sections, under the heading of "Introduction", "Teachers", "Physicists", "Physics Q&A", "Further Physics" and "Useful Links". The website provides teachers with the resources that are supporting the reforms of the Physics Curriculum. Most resource materials (e.g. worksheets, PowerPoint presentations, video clips and diagrams) are accessible by the general public while some teaching materials are for registered users only. *Physics World* is a dynamic site with new content being added on a regular basis.

2. Contextual Physics

   http://www.hk-phy.org/contextual/
   The homepage of this website offers an extensive collection of links to resources in teaching, tryouts, curriculum and references to advocate contextual approach in physics teaching. Forum and sharing area for teachers are also provided. Topics include "Motion", "Force", "Momentum", "Energy", "Temperature", "Heat", "Heat Transfer" and "Change of States" to support the contextual approach.

3. Ocean Park

   http://www.hk-phy.org/oceanpark/
   This website provides resource materials to support learning beyond classroom. Learning activities, worksheet and video clips for "Turbo Drop", "Cable Car", "Ocean Theatre", "Roller Coaster" and "Tower in the Ocean Park" are provided for download. Teachers can also download "Motion Analysis Software" to analyse the motion of an object (e.g. dolphin high jump and turbo drop) in the video clips.

4. Data Logging in the Teaching of Physics

   http://data-log.hkedcity.net/physics/index.html
   This website provides a comprehensive collection of teaching resource materials for using data logger in the teaching of physics. Topics include "Mechanics", "Electricity and Magnetism", "Optics and Waves", and "Heat and Energy". Within each topic there is collection of experiments and suggested teaching activities. From

the homepage access is available to such areas as the operation, interface, sensor, software and vendor.

5. Reading to Learn

http://resources.edb.gov.hk/physics/index_e.html

The Enhancing Science Learning through Electronic Library provides physics teachers with resources for promoting reading to learn. Essays from local physicists are provided both in English and Chinese versions. These essays cover a wide range of subject areas that will lead students to interesting reading on bridges, buildings, integrated circuits, lasers, microwaves, laser speed detection, telecommunication, solar power, smart materials, binary stars, and others. This website is full of links that will lead teachers and students to extensive reading materials. Follow-up activities and suggested teaching activities are provided so that many readers can make use of it.

6. Glossary in Physics

http://cd1.edb.hkedcity.net/cd/science/glossarysci_eng.html

This website provides an interactive web-based platform for teachers and students to find English-Chinese glossary of terms commonly used in the teaching of physics in secondary schools. Key words search is offered.

7. Subject web-site in HKEdCity – Physics

http://iworld.hkedcity.net/physics

This website offers a platform to share teaching ideas, mock examination tests, lesson plans, laboratory activities, video clips and photos among physics teachers. Under "Share Resources Section", there are 14 folders offering interesting and useful resources for download. For example, selecting the link to project work one will find archives of information on the preparation and construction of a water rocket. The website also posts news, forum, useful links and teacher training programs for teachers.

8. Energy Efficiency

http://www.hk-phy.org/energy/index_e.html

This site provides a very comprehensive information related to (1) power production, (2) domestic energy efficiency, (3) commercial/industrial energy efficiency and (4) alternative sources of energy to support the "Energy and Use of Energy" of the Elective Part in the Physics Curriculum. Worksheets, video clips and Flash animation programmes are provided for registered users. It also includes an interactive e-learning platform to foster cyber-learning for energy and use of energy.

9. Writing and Application of Physics Specific Genres

http://edb.hkedcity.net/phygenres/en/index.htm

This website contains notes on genres, instructional design, on-line interactive exercises and relevant reference materials of the commonly-used physics specific genres. Teachers can make use of these materials to teach students the physics specific genres and ultimately help them improve their writing skills in physics.

Chemistry Resources

	Title	Category	Year of Production
1.	Chemistry Cliparts http://cd1.edb.hkedcity.net/cd/science/chemistry/zipfile/clipart.zip	Computer Software	1999
2.	Pronunciation of Chemical Terms http://cd1.edb.hkedcity.net/cd/science/chemistry/resource/reference/rc3.html	Website	1999
3.	Online Glossary of Chemical Terms http://cd1.edb.hkedcity.net/cd/science/glossarysci_eng.html	Website	1999
4.	Modern Chemical Techniques http://resources.edb.gov.hk/chemtech	CD ROM & Website	2000
5.	Inquiry-based Chemistry Experiment	Booklet	2002
6.	Chemistry Animations http://cd1.edb.hkedcity.net/cd/science/chemistry/resource/animations/index.htm	CD ROM & Website	2003
7.	Reactions of Metals http://cd1.edb.hkedcity.net/cd/science/chemistry/resource/reactions/main.html	CD ROM & Website	2003
8.	Exemplars of Learning Materials for S4-5 Chemistry	Booklet	2003
9.	Nomenclature of Organic Compounds http://cd1.edb.hkedcity.net/cd/science/chemistry/resource/naming/intro.htm	CD ROM & Website	2004
10.	Resource book for sixth-form practical chemistry	Booklet	2004
11.	Exemplars of Learning and Teaching Activities for the Sixth Form Chemistry Curriculum	Booklet	2005
12.	Visualizing Chemistry http://cd1.edb.hkedcity.net/cd/science/chemistry/resource/VC/index.html	CD ROM & Website	2006
13.	Investigative Study in Chemistry – Exemplars of Learning and Teaching Activities	Booklet	2009
14.	Promoting the Quality of Chemistry Learning with Active Reading and Writing Tasks – Exemplars of Learning and Teaching Activities http://cd1.edb.hkedcity.net/cd/science/chemistry/zipfile/active_rw.zip	Booklet & CD ROM	2008

Title	Category	Year of Production
15. Writing with Chemistry Specific Genres http://resources.edb.gov.hk/~science/genre/index-e.html	Booklet & Website	2012
16. Chemistry Experiment Techniques http://minisite.proj.hkedcity.net/chemtech/eng/index.html	Website	2013
17. Safety in Science Laboratories	Booklet	2013

Biology Resources

	Title	Category	Year of Production
1.	Cells and Cellular Processes	CD-ROM	2008
2.	Curriculum Resources for Infusing Ideas about Nature and History of Biology and Scientific Inquiry into the Learning and Teaching of the Senior Secondary Biology Curriculum	Folder & CD-ROM	2009
3.	Curriculum Resources for Infusing Science – Technology – Society – Environment Connections into the Learning and Teaching of the Senior Secondary Biology Curriculum	Folder & CD-ROM	2009
4.	Learning and Teaching Resources for Senior Secondary Biology Curriculum: Problem-based Learning	Folder & CD-ROM	2009
5.	An English-Chinese Glossary of Terms Commonly Used in the Teaching of Biological Sciences in Secondary Schools http://cd1.edb.hkedcity.net/cd/science/glossarysci.html	Online	2007
6	Combined Science (S4-6) (Biology Part) Curriculum Supplementary Document http://www.edb.gov.hk/en/curriculum-development/kla/science-edu/ref-and-resources/biology.html	Online	2014

Glossary

Term	**Description**
Applied Learning (ApL, formerly known as Career-oriented Studies)	Applied Learning (ApL, formerly known as Career-oriented Studies) is an essential component of the senior secondary curriculum. ApL uses broad professional and vocational fields as the learning platform, developing students' foundation skills, thinking skills, people skills, values & attitudes and career-related competencies, to prepare them for further studies and/or for work as well as for lifelong learning. ApL courses complement 24 subjects, diversifying the senior secondary curriculum.
Assessment objectives	The outcomes of the curriculum to be assessed in the public assessment.
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 embraces curriculum aims, curriculum organisation, curriculum planning, learning and teaching, and assessment.

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 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 areas (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 teaching and learning 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 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, hence, is 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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Membership of the CDC-HKEAA Committee on Physics (Senior Secondary)

(From December 2003 to September 2013)

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	Mr LEE Wai-kit	
	Prof MAK Se-yuen	
	Dr NG Pun-hon	
	Prof NG Tai-kai	(until November 2006)
	Mr WAN Ka-kit	
	Dr WONG Siu-ling, Alice	(until September 2005)
	Mr WONG Wai-keung	
	Ms YAU Wing-yee	(from November 2005)
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	Dr LAU Yiu-hon (EDB)	(from December 2009 to April 2012)
	Mr LIU Sing-po (EDB)	(from April 2012)

Membership of the CDC-HKEAA Committee on Chemistry (Senior Secondary)

(From December 2003 to September 2013)

Chairperson:	Dr MAK Chi-keung	
Members:	Mr CHENG Kin-tak	
	Prof CHEUNG Sin-pui	
	Dr HUI Chi-kuen	(from August 2012)
	Mr HSU Hung-cheung	
	Mr KWONG Tat-hay	(until July 2012)
	Mr KWONG Tsz-kin	(from August 2012)
	Mr LEI Keng-lon	
	Mr LEUNG Pang	
	Ms MA Wai-chi	(from August 2012)
	Prof NG Kee-pui, Dennis	
	Mr PUN Kwong-cheung	
	Prof Peter TANNER	(until February 2012)
	Prof WONG Wing-tak	
	Prof YEUNG Lam-lung	(from June 2012)
	Mr YEUNG Wai	(from August 2012)
Ex-officio Members:	Dr FONG Wai-hung, Raymond (EDB)	
	Dr LI Tak-man (HKEAA)	
Secretary:	Ms CHENG Siu-lin, Sophia (EDB)	

Membership of the CDC-HKEAA Committee on Biology (Senior Secondary)

(From December 2003 to September 2013)

Chairperson:	Prof TAM Fung-yee, Nora	
Members:	Ms CHENG Lai-yun	
	Prof FUNG Ming-chiu	
	Ms HO Ngar-yin, Assunta	
	Mr LAW Kim-hung, Thomas	(from February 2012)
	Dr LEE Yeung-chung	
	Mr MA Hing-tak	
	Dr MAK, William	(from September 2008)
	Dr MAN Wai-hin	(until February 2012)
	Mr NG Yau-keung, Benjamin	
	Mr PAK Chi-on	
	Prof TSAO Sai-wah, George	(until September 2008)
	Prof TSIM Wah-keung, Karl	(from February 2012)
	Dr WONG Kong-chu, Chris	(until February 2012)
	Mr WONG Leung-kwan	(until January 2010)
	Ms WONG Po-ling	(from February 2010)
Ex-officio Members:	Ms CHUNG Oi-lin, Irene (EDB)	
	Ms CHOY Siu-kwan (HKEAA)	(until September 2008)
	Mr TSUI Chi-shing, Ben (HKEAA)	(from September 2008)
Secretary:	Mr SO Chi-shing, Jason (EDB)	

Membership of the CDC-HKEAA Committee on Physics

(From September 2013 to August 2015)

Chairperson:	Prof HUI Pak-ming
Members:	Prof CHAN Kwok-sum
	Mr HO Yau-sing, Willie
	Mr HONG Chung-yin
	Dr KWOK Ping-wai
	Mr LAW Man-wai
	Mr LEUNG Ngai-chung
	Dr LO Wai-chau, Edward
	Dr NG Pun-hon
	Mr WONG Kim-wah
	Ms YAU Wing-yee
	Mr YING Pui-chi, Bosco
Ex-officio Members:	Dr LAU Yiu-hon (EDB) (from September 2013 to December 2013)
	Mr CHOI Chit-kai (EDB) (from January 2014)
	Mr SZETO Yuk-tong (HKEAA)
Secretary:	Mr LIU Sing-po (EDB) (from September 2013 to December 2013)
	Dr LAU Yiu-hon (EDB) (from January 2014)

Membership of the CDC-HKEAA Committee on Chemistry

(From September 2013 to August 2015)

Chairperson:	Mr PUN Kwong-cheung
Members:	Mr CHOW Ka-kui
	Prof CHOW Cheuk-fai, Stephen
	Dr HUI Chi-kuen
	Mr KWONG Tsz-kin
	Ms LAM Sin-yee
	Dr MAK Kin-wah, Kendrew
	Mr NG Kai-bun, Anthony
	Mr NG Wa-piu, Henry
	Ms SOO May-Kei
	Dr TONG Pui-ling, Angela
	Ms WONG King-lok, Victoria
	Mr YEUNG Wai
	Prof YEUNG Lam-lung
Ex-officio Members:	Dr FONG Wai-hung, Raymond (EDB)
	Dr LI Tak-man (HKEAA)
Secretary:	Ms CHENG Siu-lin, Sophia (EDB)

Membership of the CDC-HKEAA Committee on Biology

(From September 2013 to August 2015)

Chairperson:	Prof TSIM Wah-keung, Karl
Members:	Mr CHEN Yau-hip, Louis
	Prof CHENG May-hung, May
	Dr CHEUNG Siu-gin
	Ms HO Hoi-ying
	Ms HO Ngar-yin, Assunta
	Dr LAI Chun-hong
	Mr LAM Pui-chow
	Mr LAW Kim-hung, Thomas
	Mr NG Yau-keung, Benjamin
	Mr TANG Chi-yin
Ex-officio Members:	Ms CHUNG Oi-lin, Irene (EDB)
	Mr TSUI Chi-shing, Ben (HKEAA)
Secretary:	Mr SO Chi-shing (EDB)

Membership of the CDC-HKEAA Committee on Physics

(From September 2015 to August 2017)

Chairperson:	Prof CHAN Kwok-sum
Members:	Mr HO Yau-sing, Willie
	Ms LIN Chi-wan
	Mr YING Pui-chi, Bosco
	Mr CHUNG Sai-chak
	Mr LEUNG Ngai-chung
	Dr KWOK Ping-wai
	Dr PUN Chun-shing, Jason
	Dr LO Wai-chau, Edward
	Mr WONG Kim-wah
	Mr LAW Man-wai
Ex-officio Members:	Mr CHOI Chit-kai (EDB)
	Mr SZETO Yuk-tong (HKEAA)
Secretary:	Dr LAU Yiu-hon (EDB)

Membership of the CDC-HKEAA Committee on Chemistry

(From September 2015 to August 2017)

Chairperson:	Mr CHOW Ka-kui	
Members:	Prof CHOW Cheuk-fai, Stephen	
	Dr HUI Chi-kuen	
	Mr KWONG Tsz-kin	
	Ms LAM Sin-yee	
	Ms LEE Po-yin	
	Dr MAK Kin-wah, Kendrew	
	Mr NG Kai-bun, Anthony	
	Mr NG Wa-piu, Henry	(from November 2015)
	Ms SOO May-kei	(from November 2015)
	Dr TONG Pui-ling, Angela	
	Ms WONG King-lok, Victoria	(from November 2015)
	Prof WONG Wing-tak	
	Mr YEUNG Wai	
	Prof YEUNG Lam-lung	
Ex-officio Members:	Dr FONG Wai-hung, Raymond (EDB)	
	Dr LI Tak-man (HKEAA)	
Secretary:	Ms CHENG Siu-lin, Sophia (EDB)	

Membership of the CDC-HKEAA Committee on Biology

(From September 2015 to August 2017)

Chairperson:	Dr CHEUNG Siu-gin
Members:	Prof CHAN Ho-yin, Edwin
	Mr CHEN Yau-hip, Louis
	Ms HO Hoi-ying
	Mr LAM Pui-chow
	Mr LAU Chun-hung
	Mr LAW Kim-hung, Thomas
	Dr MA Yin-nin
	Mr TANG Chi-yin
	Prof TSIM Wah-keung, Karl
	Dr YIP Wing-yan, Valerie
Ex-officio Members:	Ms CHUNG Oi-lin, Irene (EDB)
	Mr TSUI Chi-shing, Ben (HKEAA)
Secretary:	Mr SO Chi-shing (EDB)