Science Education

Key Learning Area Curriculum Guide (Primary 1 – Secondary 6)

Prepared by
The Curriculum Development Council

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The Education Bureau
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Preamble

The development of the Hong Kong school curriculum has advanced into a new phase of ongoing renewal and updating. It ushers in a new era for curriculum development to keep abreast of the macro and dynamic changes in various aspects in the local, regional and global landscapes in maintaining the competitiveness of Hong Kong. For the ultimate benefits of our students, schools are encouraged to sustain and deepen the accomplishments achieved since the Learning to Learn curriculum reform started in 2001, and to place new emphases on future needs in curriculum development for achieving the overall aims and learning goals of the school curriculum.

The eight Key Learning Area (KLA) Curriculum Guides (Primary 1 - Secondary 6) have been updated and recommended by the Curriculum Development Council (CDC)[1] to support the ongoing renewal of the school curriculum at the primary and secondary levels.

In updating the KLA Curriculum Guides, the respective KLA committees under the CDC have taken into consideration the concerns, needs and suggestions of various key stakeholders including schools, principals, teachers, students and the public at large. A series of school briefing cum feedback collection sessions coupled with a territory-wide school survey were conducted in 2015 to gauge schools' views on the major updates of the respective Curriculum Guides.

The eight KLA Curriculum Guides (2017) supersede the 2002 versions. Each KLA Curriculum Guide presents the updated curriculum framework which specifies the KLA's curriculum aims, learning targets and objectives, delineates the direction of ongoing curriculum development at the KLA level, and provides suggestions on curriculum planning, learning and teaching strategies, assessment, as well as useful learning and teaching resources. In addition, updated examples of effective learning, teaching and assessment practices are provided for schools' reference. Supplements to some KLA Curriculum Guides and subject curriculum guides are also available to provide further suggestions on their implementation at specific key stages. Schools are encouraged to adopt the recommendations in the KLA Curriculum Guides, taking into account the school contexts, teachers' readiness and learning needs of their students.

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[1] The CDC is an advisory body offering recommendations to the Government on all matters relating to school curriculum development from kindergarten to secondary levels. Its membership includes heads of schools, teachers, parents, employers, academics from tertiary institutions, professionals from related fields or related bodies, representatives from the Hong Kong Examinations and Assessment Authority (HKEAA), and officers from the Education Bureau.

For a better understanding of the interface between various key stages and connections of different learning areas, and how effective learning, teaching and assessment can be achieved, schools should make reference to all related curriculum documents recommended by the CDC and the latest versions of the Curriculum and Assessment Guides jointly prepared by the CDC and the HKEAA for the senior secondary curriculum to ensure coherence in curriculum planning at the school, KLA and subject levels.

As curriculum development is a collaborative and ongoing process, the KLA Curriculum Guides will be under regular review and updating in light of schools' implementation experiences as well as the changing needs of students and society.

Views and suggestions on the development of the Science Education KLA Curriculum are always welcome. These may be sent to:

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Key Messages

Science Education Key Learning Area

The Science Education Key Learning Area (KLA) is an integral part of the school curriculum that provides a wide range of learning experiences for students to:

- develop scientific literacy with a firm foundation in science, realise the important relationship among science, technology, engineering and mathematics, and master integration and application of relevant knowledge and skills across KLAs; and

- develop positive values and attitudes for personal development and for contributing to a scientific and technological world in the 21st century

Entitlement of Students

- All students from Primary 1 to Secondary 3 are entitled to science education. At the primary level, the science learning elements are included in different strands of the General Studies curriculum. Students develop their interest in science and basic scientific knowledge and science process skills to facilitate their progression to learning in secondary schools. At the junior secondary level, the Science (S1-3) curriculum enables students to further develop their scientific knowledge and skills and provide a firm foundation for them to pursue their studies at the senior secondary level.

- At the senior secondary level, students can extend their learning by studying one or more Science elective subjects including Biology, Chemistry, Physics, Science (Mode I: Integrated Science; Mode II: Combined Science) and/or by engaging in science-related learning activities.

Updated Curriculum Emphases

- The emphases of the Science Education KLA curriculum have been updated with reference to the guiding principles of the ongoing renewal of the school curriculum, the learning goals for primary and secondary education, and the trend of the development of science education worldwide. The updated curriculum emphases are as follows:

- Nurturing students’ interest in science and related disciplines
- Emphasising students’ development of scientific thinking and problem solving skills
- Strengthening students’ ability to integrate and apply knowledge and skills (including hands-on skills)
- Fostering students’ sense of making informed judgements based on scientific evidence
- Nurturing students to become self-directed learners of science
- Embracing students with different needs and aspirations

Curriculum Framework for the Science Education Key Learning Area

- An open and flexible curriculum framework is adopted for the Science Education KLA. The main components of the curriculum are:

    - scientific knowledge and science process skills, which are expressed in the form of learning targets and learning objectives;
    - generic skills; and
    - values and attitudes.

- The major learning elements of the Science Education curriculum are arranged into six strands:

    - Scientific Investigation
    - Life and Living
    - The Material World
    - Energy and Change
    - The Earth and Beyond
    - Science, Technology, Society and Environment (STSE)

- Elements of Science, Technology, Engineering and Mathematics (STEM) education are embedded in the Science Education curriculum framework to emphasise the increasing importance of integrating and applying knowledge and skills within the Science Education KLA and across KLAs. Other Major Renewed Emphases (MRE) of the ongoing renewal of the school curriculum including Information Technology in Education (ITE) and Language across the Curriculum (LaC) are also included in the curriculum framework to highlight their relevancy and importance in science education.

Curriculum Planning

- The *Science Education KLA Curriculum Guide (Primary 1 – Secondary 6)* (2017) sets the direction of the Science Education curriculum from the primary to secondary levels. It provides a central curriculum for the Science Education KLA in the form of an open and flexible framework comprising strands, learning targets and objectives, and major learning contents.

- Schools should refer to the recommendations highlighted in the Science Education KLA Curriculum Guide to ensure that students acquire opportunities of learning science. The Science Education KLA Curriculum Guide should not be regarded as a prescribed uniform syllabus for all schools and students. With reference to the framework of the central curriculum, schools should develop their own Science curriculum with due consideration of the school contexts.

- Schools should also refer to the curriculum documents for the General Studies curriculum for KS1 and KS2, the Science curriculum for KS3 and the Science elective subjects for KS4 for suggestions on the planning and development of their school Science curriculum as well as the strategies for learning, teaching and assessment at different key stages.

- Holistic curriculum development is recommended to ensure vertical continuity and lateral coherence in the planning of a school Science curriculum.

Learning and Teaching of Science

- The learning and teaching of science should aim to develop students to become self-directed and lifelong learners. It is necessary to help students build up deep learning competencies in order to develop the ability to acquire, integrate and apply knowledge and skills to solve authentic or real-life problems.

- A variety of learning experiences should be provided for students to collaborate with others, construct their own meaning, plan, manage and make choices and decisions about their learning, so that students could internalise newly acquired knowledge and skills, and develop a greater sense of ownership in learning.

- Owing to students' diverse needs and specific targets in different learning contexts, teachers need to have a thorough understanding of different pedagogical approaches to designing and providing meaningful learning experiences. Learning and teaching strategies such as practical work, investigation, discussion, role-play, debate, context-based learning, problem-based learning and project learning are deemed suitable for the learning and teaching of science.

- Many scientific, technological and engineering advancements are cross-disciplinary in nature. Therefore, the learning elements of other STEM-related disciplines should be included in the learning and teaching of science to enhance students' interest and innovation and to develop their ability to integrate and apply knowledge and skills across disciplines.

Assessment

- Assessment is an integral component of the curriculum, pedagogy and assessment cycle. It provides the information needed for students to plan, improve and self-regulate their own learning. From the student-centred perspective, assessment activities have moved away from simply allowing students to demonstrate their learning outcomes or achievements to integrating with learning and teaching, and helping students conduct self-reflection to improve their own learning.

- For the learning and teaching of science, different modes of assessment (e.g. pen and paper test, written assignment, oral questioning, observation, e-assessment, practical assessment, project work and portfolio) can be adopted by Science teachers to build up a comprehensive picture of students' achievements and to provide timely and quality feedback for their ongoing learning and development.

Resources and Support

- A good variety of resources should be used to enhance the effectiveness of the learning and teaching of science. Besides textbooks, schools should use other relevant resource materials to help students develop their scientific knowledge and skills, provide them with learning experiences beyond the school hours to extend their learning, address diverse learning needs and promote self-directed learning.

- To promote science education and STEM education, schools are encouraged to make effective use of resources and learning activities developed/organised by the EDB, other government departments, tertiary institutions, professional bodies and non-governmental organisations. Students should participate in life-wide learning activities including exhibitions, competitions, visits, field trips, surveys and workshops. Curriculum leaders and teachers should participate in professional development activities such as symposia, seminars, workshops, communities of practice, and meetings with academics in the territory, the Mainland and overseas.

Major Renewed Emphases of the Ongoing Development of the Science Education KLAs

- Suggestions for the development and implementation of the Science Education KLA in the five to ten years to come include the following:
    - Emphasising scientific literacy
    - Promoting STEM education
    - Promoting Language across the Curriculum and enhancing development of generic skills, values and attitudes in a holistic manner
    - Emphasising holistic curriculum planning and cross-KLA collaboration
    - Promoting Information Technology in Education, e-learning and information literacy to develop self-directed learning
    - Embracing learner diversity and using appropriate strategies to support SEN and gifted students

For more information on various curriculum matters, please refer to the *Basic Education Curriculum Guide (Primary 1 – 6)* (2014) and the *Secondary Education Curriculum Guide (Secondary 1 - 6)* (2017).

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Introduction

Chapter 1 Introduction

In response to the changing needs of society, the rapid development of science, technology and engineering in the world, the views of stakeholders collected through various surveys and engagement activities as well as the need to align with the direction for the ongoing renewal of the school curriculum, the recommendations provided in the *Science Education Key Learning Area Curriculum Guide (Primary 1 - Secondary 3)* (2002) have been reviewed. Building on the strengths of Hong Kong students in science, the curriculum emphases of the Science Education Key Learning Area (SE KLA) have been updated, together with the aims, targets and objectives of the SE KLA for different key stages, to highlight the Major Renewed Emphases (MRE) of the ongoing renewal of the school curriculum, in particular STEM[2] education. Given that elements of STEM education are already embedded in individual KLAs of Science Education, Technology Education and Mathematics Education of the school curriculum, there is a need to further strengthen the coherence and collaboration among KLAs. In this connection, the promotion of STEM education is a development focus to further enhance the quality and effectiveness of learning, hence enabling students to become more effective lifelong learners in the 21st century.

The ***Science Education Key Learning Area Curriculum Guide (Primary 1 - Secondary 6)*** (2017) (this Guide) is prepared by the Curriculum Development Council (CDC) Committee on Science Education. It is an updated version of the *Science Education Key Learning Area Curriculum Guide (Primary 1 - Secondary 3)* (2002) and has been extended to include the three-year senior secondary Science Education curriculum to provide reference for schools in developing a coherent school Science curriculum.

The direction for the development of this Guide aligns with the Seven Learning Goals of Primary and Secondary Education (see Appendix 1 for the Seven Learning Goals of Primary Education and the Updated Seven Learning Goals of Secondary Education) and the major recommendations in the ***Basic Education Curriculum Guide – To Sustain, Deepen and Focus on Learning to Learn (Primary 1 - 6)*** (2014) and the ***Secondary Education Curriculum Guide (Secondary 1 – 6)*** (2017).

This Guide provides the overall direction for the development of the Science Education curriculum in the five to ten years to come. It reinforces the curriculum emphases provided

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[2] STEM is an acronym that refers collectively to the academic disciplines of Science, Technology, Engineering and Mathematics. In the Hong Kong curriculum context, STEM education is promoted through the Science, Technology and Mathematics Education KLAs.

in the *Science Education Key Learning Area Curriculum Guide (Primary 1 - Secondary 3)* (2002) to enhance learning and teaching and puts forth MRE which take into account the significant developments in our society and around the world in various fields, and for the ultimate benefits of student learning. This Guide includes examples relevant to different key stages of learning to illustrate the concepts and ideas introduced and to narrow the gaps in curriculum implementation. A supplement to this Guide is also available to provide further suggestions on the implementation of the Science curriculum at Key Stage 3 (Secondary 1 - 3).

Schools should make reference to the following curriculum documents for suggestions on the planning and development of their school Science curriculum as well as the strategies for learning, teaching and assessment at different key stages:

- *General Studies for Primary Schools Curriculum Guide (Primary 1 - 6)* (2017)
- *Supplement to the Science Education Key Learning Area Curriculum Guide: Science (Secondary 1 – 3)* (2017)
- *Biology, Chemistry, Physics, Combined Science and Integrated Science Curriculum and Assessment Guides (Secondary 4 - 6)* (2007) (with updates in November 2015)

1.1 What is a Key Learning Area?

A Key Learning Area is an important part of a curriculum. It is founded on fundamental and connected concepts within major fields of knowledge which should be acquired by all students. A KLA provides a context for the development and application of generic skills (e.g. communication, critical thinking and collaboration skills, creativity), subject-specific skills, as well as positive values and attitudes through appropriate use of learning and teaching activities and strategies. It serves as a context for the construction of new knowledge and the development of understanding. The studies offered in each KLA may have an academic, social or practical orientation or a combination of these, depending on their purpose(s). They can be organised into subjects, modules, units, tasks or other modes of learning.

The three interconnected components of the curriculum framework, i.e. Knowledge in Key Learning Areas, Generic Skills, and Values and Attitudes can be represented in Figure 1.1:

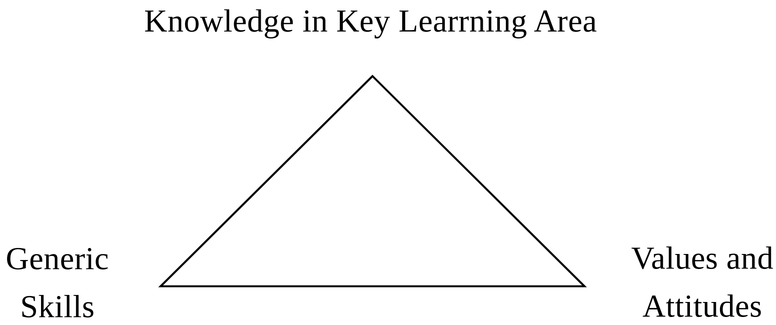

Figure 1.1 Three Interconnected Components of the Curriculum Framework

1.2 Position of the Science Education KLA in the School Curriculum

Science is the study of phenomena and events around us through systematic observation and experimentation. Science education cultivates students’ curiosity about the world and enhances scientific thinking. Through systematic inquiry, students will develop scientific knowledge and skills to help them evaluate the impact of scientific and technological developments. This will prepare students to become lifelong learners in science and technology and responsible citizens, and to contribute to our scientific and technological world.

1.2.1 Promoting Scientific Literacy

In face of globalisation and the rapid technological developments in the 21st century, even people outside the science professions tend to focus on the scientific dimension on issues of concerns. In a world city like Hong Kong, many people find a knowledge and understanding of science useful to their work and a competency in scientific inquiry valuable in solving daily life problems. In media reports and public discussions, we often come across issues related to public health, energy, environment, etc. We also encounter products and services that make scientific claims or are packaged with scientific jargons. Modern citizens need to possess scientific knowledge and apply problem solving skills for assessing the risks and benefits, and for making informed decisions on personal, social and global scientific issues. Therefore, it is essential for all students to be scientifically literate in order to live in and contribute to this scientific and technological world.

Scientific literacy refers to the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. Science education promotes scientific literacy through equipping students with knowledge of science, and facilitating their understanding of nature of science and acquisition of science process skills. This enables students to participate intelligently in public discourse about important issues that involve science, technology, society and environment. A scientific literate person is able to apply scientific knowledge and science process skills to tackle issues and problems related to their daily life and the natural world. A scientific habit of mind is of increasing importance to our students. It helps prepare them to deal sensibly with problems and uncertainties, and this often involves examination of evidence, quantitative considerations, logical arguments and creativity. To lead a fulfilling and responsible life and to facilitate career development, students need to be able to learn, reason, think creatively, communicate logically, make decisions, and solve problems. An understanding of science and the processes of science can facilitate the development of these skills.

1.2.2 Strengthening the Ability to Integrate and Apply Knowledge and Skills across STEM-related KLAs

Recent scientific, technological, engineering and mathematical developments are usually cross-disciplinary in nature. Learning in the Science Education KLA should be closely linked with the KLAs of Technology Education and Mathematics Education. To maintain the international competitiveness of Hong Kong for the challenges ahead, an innovative and collaborative culture needs to be developed with scientifically and technologically literate citizens in the community. The promotion of STEM education in schools is believed to be a feasible means to achieve these goals.

Through renewing the curriculum and enriching relevant learning activities, we hope to develop a strong knowledge base in STEM-related disciplines among students and strengthen their ability to integrate and apply knowledge and skills across disciplines, so as to nurture their creativity, innovativeness, collaboration and problem solving skills, which are the essential skills and qualities required in the 21st century.

We also hope to help students understand that the developments in science, technology, engineering and mathematics are closely related to the societal environment, and that the advancement in science and technology could improve the life of mankind in the contemporary world and enhance the economic growth and sustainable development of Hong Kong. While developing knowledge and skills across disciplines, students could also develop positive values and attitudes essential for whole-person development. These learning opportunities can facilitate students' career exploration in STEM-related fields and nurture among students an entrepreneurial spirit which involves the development of creativity, innovativeness, problem solving, and the qualities of taking responsibilities, initiatives and calculated risks.

1.2.3 A Coherent School Science Education Curriculum

Science education in Hong Kong is implemented through related subjects at the primary and secondary levels. At the primary level, the General Studies (GS) curriculum provides opportunities for students to integrate knowledge, skills and attitudes across three KLAs, i.e. Personal, Social and Humanities Education, Science Education and Technology Education. Science learning elements are included in different strands of the GS Curriculum. At the junior secondary level, all students study Science (S1 - 3) as a core subject consisting of topics from various science-related disciplines.

Science education at the primary and junior secondary levels lays a firm foundation for further developing the students' scientific literacy. For students beyond S3, provisions are available for a more in-depth understanding of different scientific disciplines. A diversified senior secondary Science Education curriculum has been developed with different elective subjects for students to choose from, and to cater for their different interests and aptitudes. Studying these elective subjects enables students to cope with a dynamically changing environment, make informed judgements in a scientific and technological society, and prepare themselves for further studies or careers that are related to science, technology and engineering.

Subjects of the Science Education KLA

Primary Level

- General Studies (Primary 1 - 6)

Junior Secondary Level

- Science (Secondary 1 - 3)

Senior Secondary Level • Biology (Secondary 4 - 6) • Chemistry (Secondary 4 - 6) • Physics (Secondary 4 - 6) • Science Mode I: Integrated Science (Secondary 4 - 6) Mode II: Combined Science (Secondary 4 - 6)

Science Education, as one of the KLAs of the school curriculum, was critically examined as part of the holistic review of the school curriculum in 1999. Further to the Learning to Learn curriculum reform started in 2001, the aims of Science Education KLA are updated to align with the MRE of the ongoing renewal of the school curriculum to further enhance the effectiveness of students' learning, to develop their creativity and abilities to solve problems, and cultivate positive values and attitudes for whole-person development.

Riding on the experience of curriculum implementation and feedback collected from the stakeholders in the curriculum review, the Science Education curriculum framework including the learning, teaching and assessment strategies is also updated to align with the latest development in schools and the worldwide trend in science education.

The Science Education KLA curriculum, with infusion of appropriate elements from the Technology Education and Mathematics Education KLAs through a range of learning activities, not only contributes to the development of science capabilities among students, but also promotes the development of generic skills as well as positive values and attitudes. Students' learning experiences in the Science Education KLA may also be linked with other KLAs, apart from Technology Education and Mathematics Education, and holistic planning of learning experiences is necessary to facilitate effective implementation within the suggested time allocation for different key stages.

1.3 Direction for Development

Over the past decade, a strong partnership has been developed between the Education Bureau (EDB) and the school sector in the implementation of the Science Education KLA curriculum. Scientific investigation is now widely used to develop students' scientific thinking and practical skills in schools. Opportunities are also provided for students to engage in various learning activities inside and outside the classroom to enrich their science learning experiences. Over the years, priority has been given to the development of the four generic skills of communication skills, creativity, critical thinking skills and problem solving skills (i.e. 3Cs+1P), and encouraging progress has been made.

The updated Science Education KLA curriculum framework is built on the strengths and good practices in science education in Hong Kong. There are suggestions on how to provide with wider access to meaningful, enjoyable and effective science learning experiences that will enable students to meet the needs and challenges in the contemporary world. According to the international studies and the local surveys, science education in Hong Kong has continued to excel. Students, generally have motivation and interest to learn science. Teachers generally support the aims of the Science Education KLA curriculum which poses challenges to the students of different key stages.

1.3.1 Building on strengths

Science education is a core component of the school curriculum at the primary and secondary levels. Hong Kong students' good performance in science as revealed from international studies and local surveys reflects the strengths of our science education.

Science education is implemented at the primary level through the GS curriculum. Learning contexts closely related to students' daily life experiences are chosen to help them understand the impact of science and technology on society. Hands-on and minds-on learning activities are organised to develop students' curiosity and interest in science and technology. Besides, there is a greater awareness among teachers of the use of an inquiry-based approach to enhance learning and teaching.

The strength of science education at the secondary level are the strong team of subject-trained Science teachers, the availability of ample teaching resources including well-equipped science laboratories, teaching aids and library resources, and the strong support of laboratory technicians. Besides arranging sufficient science experiments and investigations for students, there is growing awareness of encouraging collaboration among teachers for holistic curriculum planning to further enhance the effectiveness of learning and teaching. Furthermore, there is increasing support from scientists, academics and professional bodies in promoting science education.

Building on the strength of science education in Hong Kong, Science teachers need to keep up with their good efforts to sustain the momentum, further enhance students' interest in science and develop their potential in science. Hong Kong students need to strengthen their knowledge base and the ability to integrate and apply knowledge and skills across disciplines. They also need to enhance their creativity, innovativeness and problem solving skills to meet the challenges in the contemporary world of science and technology. Therefore, in consideration of the guiding principles of the ongoing renewal of the school curriculum (see Section 1.6 of the SECG Booklet 1), the Updated Seven Learning Goals of Secondary Education (see Appendix A1), and the trend of the development of science education worldwide, the emphases of the Science Education KLA curriculum are updated as follows:

- Nurturing students' interest in science and related disciplines
- Emphasising students' development of scientific thinking and problem solving skills
- Strengthening students' ability to integrate and apply knowledge and skills (including hands-on skills)
- Fostering students' sense of making informed judgements based on scientific evidence
- Nurturing students to become self-directed learners of science
- Embracing students with different needs and aspirations

1.4 Curriculum Emphases and Major Focus of Development

In the ongoing renewal of the school curriculum, schools are encouraged to sustain and deepen what has been achieved in curriculum development, and help students of different abilities and backgrounds to develop their potential to the full. It is hoped that all schools will continue to adopt holistic curriculum planning and development for the Science Education KLA to meet the needs of their students with reference to the learning targets and objectives set out in this Guide.

1.4.1 Curriculum Emphases

Details of the updated curriculum emphases that help set the direction for the development of science education in Hong Kong schools are outlined as follows:

Nurturing students' interest in science and related disciplines

In general, students are born with an aspiration to explore, inquire and solve problems pertinent to their life experience. It is important to promote and sustain students' interest in learning science. Learning activities that are related to real life help motivate students to inquire about science related matters.

Teachers of GS in primary schools and Science subjects in secondary schools are encouraged to make use of investigative learning activities with hands-on and minds-on features to develop students' interest in science. It is essential that students enjoy and benefit from the learning of science through participating in a wide range of activities. They should be nurtured to own their learning and become self-directed learners of science. Besides, engaging students in discussing issues in daily life helps enhance their awareness of the connection between science and society, and increase their motivation in learning science and related disciplines.

Partnerships with tertiary institutions such as the science/engineering faculties in universities, professional bodies and science-related organisations such as the Hong Kong Science Museum help develop a range of authentic learning activities to promote science education, and to enrich students' learning experiences in science and related disciplines beyond the classroom.

Emphasising students' development of scientific thinking and problem solving skills

Due emphasis should be placed on enhancing students' scientific thinking in curriculum planning. Scientific thinking could be developed through understanding of scientific concepts and ideas, and the nature of science, as well as through acquiring science process skills. With an innovative mindset and a firm grasp of scientific knowledge and skills, students can tackle problems in the contemporary world more effectively and become better decision-makers and problem-solvers.

Students acquire science process skills through scientific investigations. Students could be guided to make observations, plan and design investigations, conduct experiments, and modify the investigations based on the results for further evolvement of findings or theories.

Strengthening students' ability to integrate and apply knowledge and skills (including hands-on skills)

Besides developing a solid knowledge base among students, teachers need to make use of learning activities of different natures (such as project learning and problem-based learning) to provide meaningful contexts that are closely geared to daily life from the personal, local, national or global perspectives for students to integrate and apply knowledge and skills (including hands-on skills) of the Science Education, Technology Education and Mathematics Education KLAs during the learning process.

While engaging in cross-disciplinary learning tasks, students would face challenges such as locating additional information from different sources, discussing or debating about the case among group members, analysing information and data, identifying the general features from the findings, developing tools for further investigation, producing useful products and participating in other follow-up activities (e.g. presentations of results/inventions). During the process of solving authentic problems, students have to integrate their knowledge of different disciplines and apply generic skills such as communication skills, mathematical skills, information technology skills, critical thinking skills, collaboration skills and creativity in the way that closely resembles scenarios in the real world.

Fostering students' sense of making informed judgements based on scientific evidence

Students' scientific literacy needs to be enhanced as they may encounter many issues related to science and technology in the contemporary world. It is the role of science education in schools to promote students' awareness and understanding of science, and to help them make informed judgements based on scientific evidence. Science learning usually involves an examination of evidence, quantitative considerations and logical arguments. Through science learning activities, students acquire knowledge and skills, and also develop a scientific habit of mind. They may then actively participate in public discourse about social and environmental issues related to science, technology and engineering.

Nurturing students to become self-directed learners of science

Learning requires active involvement of students in tasks, and the extent of their involvement depends on their sense of ownership of learning. Students should be provided with ample learning opportunities to become self-directed learners of science. They should also be guided to connect their learning experiences across KLAs to render learning more meaningful.

Teachers could engage students in designing and conducting experiments to explore scientific phenomena and develop science process skills for their construction of scientific knowledge. Learning activities could also be arranged inside and outside the classroom to expose students to the frontiers of science and promote their interests in the advancement of science, technology and engineering. Besides, they could be encouraged to make the best use of different IT resources or platforms to engage themselves in self-directed learning and peer learning of science.

Embracing students with different needs and aspirations

Schools should provide a variety of learning programmes for students to cater for their needs and aptitudes. Students with high ability or a strong interest in science need more challenging learning programmes to develop their potential to the full. The programmes may include extended learning activities which enable students to appreciate the latest developments in science, technology and engineering. A variety of learning activities such as science competitions and projects could also be arranged to develop their interest and talent in science. These activities may be arranged as school-based programmes or in collaboration with tertiary institutions, professional bodies or STEM-related organisations.

It is important to introduce appropriate support measures in consideration of students' ability and interest in learning science. For examples, schools may consider using a peer group study approach to provide learning opportunities for students who are less motivated in learning science and to enable them to have a good mastery of the basic scientific knowledge and skills essential for application in their daily life, for further studies and future careers. To fulfil the needs of economic, scientific and technological developments in the contemporary world, a pool of talents with different capabilities and at different knowledge and skill levels is needed.

1.4.2 Major Renewed Emphases of the Ongoing Development of the Science Education KLA

The following MRE are put forth in this Guide in response to the local and global changing contexts and education trends, and to provide suggestions for the development and implementation of the Science Education KLA curriculum in the five to ten years to come:

- Emphasising the importance of **scientific literacy**, through equipping students with an understanding of the **nature of science** and a firm grasp of science process skills for a strong foundation on scientific knowledge and skills;
- Strengthening students' ability to integrate and apply knowledge and skills through **STEM education**;
- Highlighting the development of **generic skills**, **values and attitudes** in a holistic manner, and promoting **Language across the Curriculum (LaC)** in planning and implementing the school Science curriculum;
- Emphasising the importance of **holistic curriculum planning** and the process of **P-I-E** (Planning-Implementation-Evaluation) for effective implementation of science education and STEM education in schools;
- Promoting **Information Technology in Education (ITE)** and **e-Learning** according to Fourth Strategy on IT in Education to motivate students' interest in learning science, enhance interaction and collaboration, and facilitate self-directed learning, and incorporating relevant learning activities to strengthen students' Information Literacy (IL) for whole-person development and lifelong learning; and
- Stressing the continued need to embrace **learner diversity** in science education, paying particular attention to students of different learning needs and styles, including students with special educational needs (SEN) and those who are gifted with special talents in science.

Relevant details of these updates are elaborated in the following chapters of this Guide.

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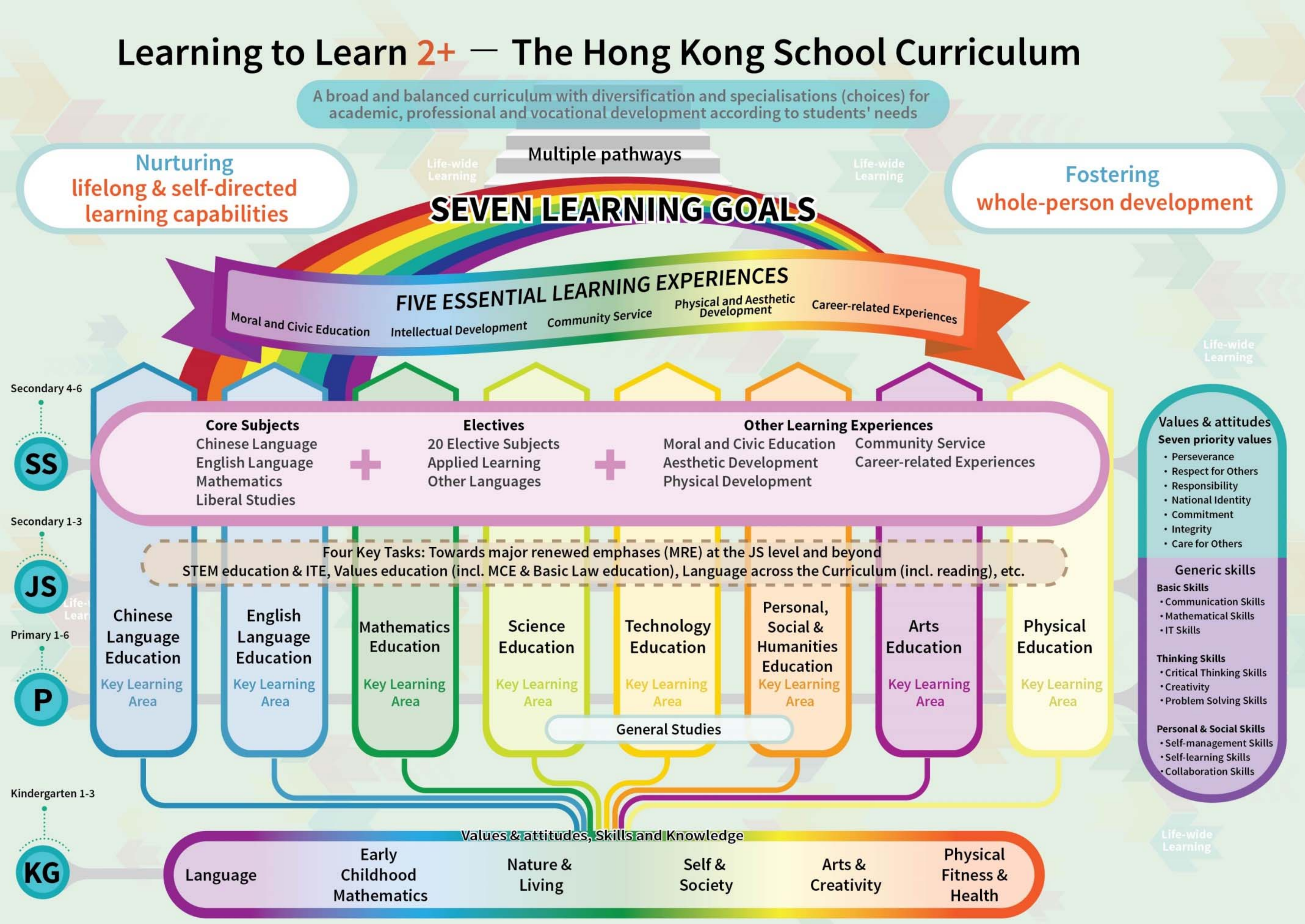
Chapter 2
Curriculum Framework


Learning to Learn 2+ — The Hong Kong School Curriculum
A broad and balanced curriculum with diversification and specialisations (choices) for academic, professional and vocational development according to students' needs
Multiple pathways
Nurturing lifelong & self-directed learning capabilities
Fostering whole-person development
Life-wide Learning
SEVEN LEARNING GOALS
FIVE ESSENTIAL LEARNING EXPERIENCES
Moral and Civic Education
Intellectual Development
Community Service
Physical and Aesthetic Development
Career-related Experiences
Secondary 4-6
SS
Secondary 1-3
JS
Primary 1-6
P
Kindergarten 1-3
KG
Core Subjects
Chinese Language
English Language
Mathematics
Liberal Studies
+
Electives
20 Elective Subjects
Applied Learning
Other Languages
+
Other Learning Experiences
Moral and Civic Education
Aesthetic Development
Physical Development
Community Service
Career-related Experiences
Four Key Tasks: Towards major renewed emphases (MRE) at the JS level and beyond
STEM education & ITE, Values education (incl. MCE & Basic Law education), Language across the Curriculum (incl. reading), etc.
Chinese Language Education Key Learning Area
English Language Education Key Learning Area
Mathematics Education Key Learning Area
Science Education Key Learning Area
Technology Education Key Learning Area
Personal, Social & Humanities Education Key Learning Area
Arts Education Key Learning Area
Physical Education Key Learning Area
General Studies
Values & attitudes
Seven priority values
• Perseverance
• Respect for Others
• Responsibility
• National Identity
• Commitment
• Integrity
• Care for Others
Generic skills
Basic Skills
• Communication Skills
• Mathematical Skills
• IT Skills
Thinking Skills
• Critical Thinking Skills
• Creativity
• Problem Solving Skills
Personal & Social Skills
• Self-management Skills
• Self-learning Skills
• Collaboration Skills
Values & attitudes, Skills and Knowledge
Language
Early Childhood Mathematics
Nature & Living
Self & Society
Arts & Creativity
Physical Fitness & Health

Chapter 2 Curriculum Framework

The curriculum framework for science education is the overall structure for organising learning, teaching and assessment for the subjects of the Science Education KLA. The framework comprises a set of interlocking components including:

- subject knowledge and skills, which are expressed in the form of learning targets and learning objectives;
- generic skills; and
- values and attitudes.

The framework sets out what students should understand, value and be able to perform at various stages of schooling. It gives schools and teachers flexibility and ownership to plan and develop their school Science curriculum to cater for the different needs and aspirations of students.

2.1 Aims of Science Education

Science education is an integral part of the school curriculum. It provides learning experiences through which students develop scientific literacy from Key Stage 1 to Key Stage 4. Students can develop the necessary scientific knowledge and science process skills, generic skills, as well as values and attitudes for their whole-person development, for participating actively in a dynamically changing society, and for contributing towards a scientific and technological world.

Aims of the Science Education KLA curriculum are for students to:

- develop curiosity and interest in science;
- develop the ability to make inquiries about science and solve problems;
- acquire scientific knowledge, science process skills and generic skills;
- develop the ability to integrate and apply knowledge and skills of science and related disciplines;
- develop an understanding of the nature of science;
- become familiar with the language of science to communicate science-related ideas;
- recognise the social, ethical, economic, environmental and technological implications of science, and develop an attitude for responsible citizenship and a commitment to promote personal and community health;

- become lifelong learners of science for personal development; and
- be prepared for further studies or future careers in scientific, technological and engineering fields.

2.2 The Curriculum Framework

An open and flexible curriculum framework is adopted for the Science Education KLA. For the purpose of curriculum planning and organisation, the major learning elements of the Science Education curriculum are arranged into six strands, namely

- **Scientific Investigation**
- **Life and Living**
- **The Material World**
- **Energy and Change**
- **The Earth and Beyond**
- **Science, Technology, Society and Environment**

STEM education and MRE of the ongoing renewal of the school curriculum are also included in the curriculum framework. Through appropriate connection and integration of the six strands, effective promotion of STEM education and infusion of generic skills, values and attitudes, LaC and ITE in curriculum planning, learning and teaching, and assessment, it is hoped that students could develop scientific literacy with a firm foundation in science, realise the relationship between science, technology, engineering and mathematics, master the integration and application of knowledge and skills within and across KLAs, and develop positive values and attitudes for personal development and for contributing to a scientific and technological world.

Figure 2.1 is a diagrammatic representation of the updated Science Education curriculum framework which comprises the six strands and MRE to focus on in the planning and implementation of science education in schools across different key stages.

Science Education

Science education provides learning experiences for students to develop scientific literacy with a firm foundation in science, realise the relationship between science, technology, engineering and mathematics, master the integration and application of knowledge and skills within and across KLAs, and develop positive values and attitudes for personal development and for contributing to a scientific and technological world.

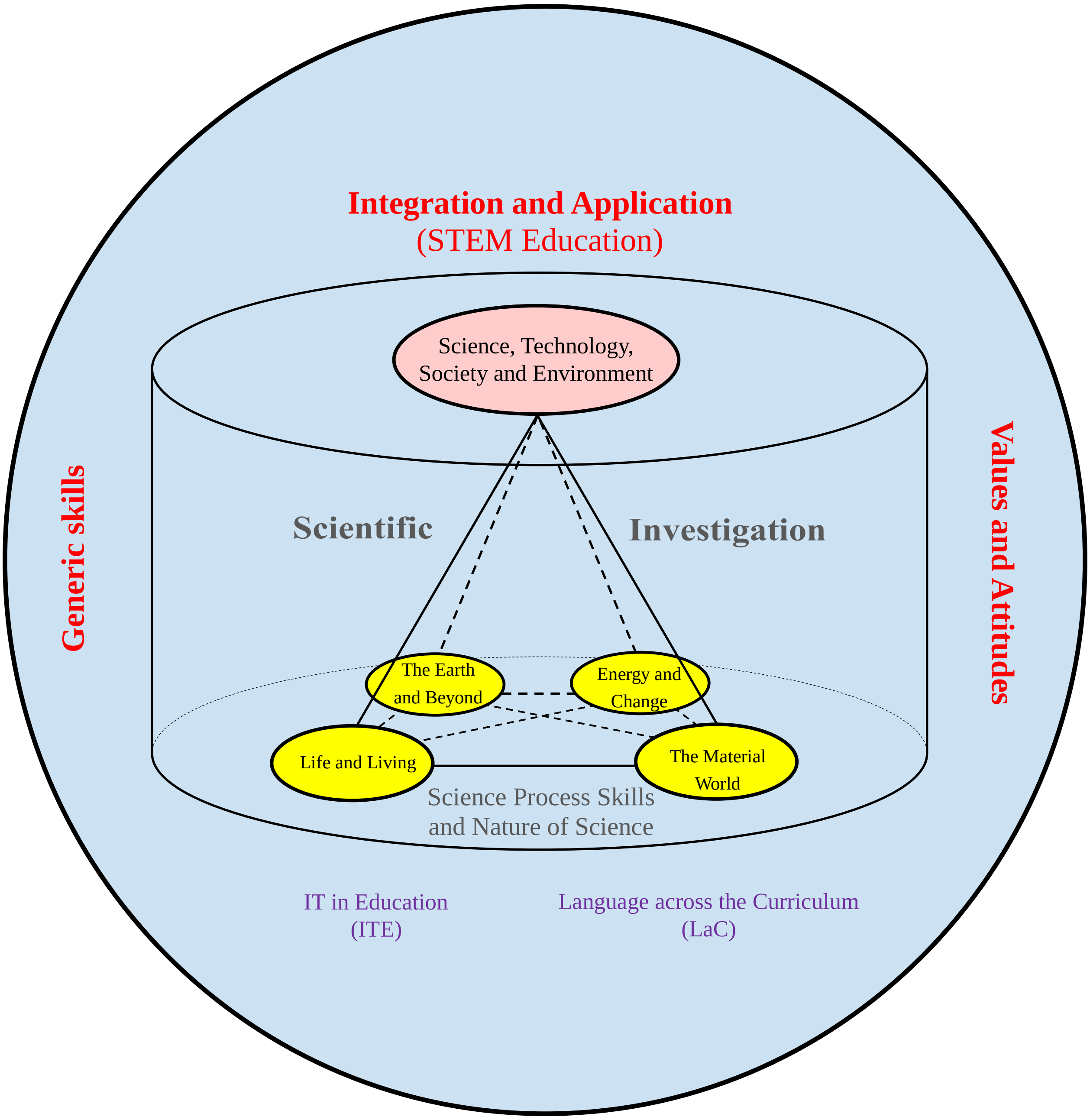


Figure 2.1 Diagrammatic Representation of the Science Education Curriculum Framework

2.2.1 Strands, Learning Targets and Objectives

Strands

The six strands of the Science Education curriculum encompass the major learning elements and are of equal importance. Their interrelationship is illustrated in Figure 2.1 with a pyramid with the following features.

- The strands of **Life and Living**, **The Material World**, **Energy and Change**, and **The Earth and Beyond** form the base of the pyramid. They represent the content areas of respective domains for developing students' understanding of relevant scientific concepts and ideas. These four strands of content areas are not isolated but inter-connected.

- The strand of **Science, Technology, Society and Environment (STSE)** rests on the top of the pyramid and is linked with the four strands of content areas at its base, showing that connections with STSE need to be addressed in each content area. Elements of **STEM education** that emphasise the ability to integrate and apply knowledge and skills are intrinsically embedded in the strand of STSE. Technological and engineering applications are widely used to illustrate the significance of scientific discoveries to societal and economic developments. Besides, mathematics is widely recognised as an indispensable tool for learning science.

- The strand of **Scientific Investigation**, through which students develop their **science process skills** and enhance their understanding of the **nature of science**, infuses into each of the other five strands.

Science process skills

Science process skills are the skills involved in the process of performing scientific investigations and they form the foundation for the scientific method. The development of various science process skills enables students to solve problems logically and sensibly, so it is essential for students to master these skills in studying science. Science process skills not only facilitate students' understanding of the nature of science but also help them develop positive values and attitudes towards science.

The essential science process skills are:

- Observing
- Classifying
- Designing investigations
- Conducting practicals
- Inferring
- Communicating

Details of the above science process skills are given in the table below:

Table 1 Science Process Skills

Science process skills	Notes
Observing	• Stating characteristics • Measuring sensibly and accurately • Recording data
Classifying	• Comparing similarities and differences • Grouping and ordering • Constructing keys • Stating relationships (including cause and effect)

Science process skills	Notes
Designing investigations	• Asking questions • Predicting results • Making hypotheses • Identifying variables • Suggesting operational procedures with consideration for fair testing
Conducting practicals	Hands-on practice including: • Choosing apparatus • Handling apparatus • Taking precautions
Inferring	• Analysing and interpreting data • Evaluating data • Estimating errors • Constructing explanations • Drawing conclusions
Communicating	• Using multiple representations to present information and ideas • Putting forward logical scientific arguments

Nature of science

Nature of science is an essential learning element in the Science Education curriculum. It refers to the beliefs and attitudes towards the knowledge about the natural world, the methods and processes through which scientific knowledge is acquired, and the socio-cultural and historical influences involved. The study of the nature of science could increase students' learning interests, enhance their understanding of scientific knowledge, and facilitate them to make informed decisions about science-related issues in their daily life.

The following are some widely accepted views of the nature of science:

- Science attempts to explain natural phenomena based on the belief that there are consistent patterns in the universe.
- Scientific knowledge is durable and tentative.
- Scientific knowledge is supported by evidence and empirical standards.
- Scientific knowledge relies on creativity, innovation and scepticism.
- Scientists use different methods according to the nature of the phenomena studied and the history of the related disciplines.
- Scientific methods include the empirical testing of new ideas generated by deductive and /or inductive logic.
- Scientists are aware of possible bias in recording, reporting and interpreting data.
- Scientists form a community, in which they make open-minded discussions, critically assess and review new ideas, and share collective wisdom.
- Science has its limitation.

Promoting STEM education

In the local curriculum context, STEM education is promoted through the Science, Technology and Mathematics Education KLAs. The aims of promoting STEM education in schools are to strengthen the science, technology and mathematics education and to nurture versatile talents with different levels of knowledge and skills for enhancing the international competitiveness of Hong Kong. The objectives of promoting STEM education in relation to student learning are:

- to develop among students a solid knowledge foundation and to enhance their interests in Science, Technology and Mathematics for further studies and careers in face of the changes and challenges in the contemporary world; and
- to strengthen students' ability to integrate and apply knowledge and skills, and to nurture students' creativity, collaboration and problem solving skills, as well as to foster the innovation and entrepreneurial spirit as required in the 21st century

Through integration and application of knowledge and skills of the KLAs of Science, Technology and Mathematics Education, students will realise that the development of science, technology and mathematics is closely related to the societal environment and that the advancement in science and technology could help improve the life of mankind in the contemporary world.

The experiences of integrating and applying knowledge and skills to solve authentic problems and make inventions will help students develop positive values and attitudes as part of their whole-person development. These experiences will not only enhance students' interest in STEM-related fields, but also equip them with the relevant knowledge, skills and attitudes for their future studies and careers in these fields.

Learning Targets

Throughout various stages of schooling, students will acquire the necessary knowledge, skills, and values and attitudes in science education. The learning targets of science education for primary, junior secondary and senior secondary levels are provided as follows.

Learning targets for students at the primary level (Key Stage 1 and 2, Primary 1 - 6) are to:

- show curiosity and interest in science;
- use their knowledge and understandings of science to explain some familiar phenomena in daily life;
- develop science process skills to explore, investigate and suggest solutions for simple scientific problems;
- relate their experience of science and technology learning to everyday life;
- develop sensitivity to safety issues related to science and technology in everyday life; and
- have basic understanding of respecting and caring for the environment and the living things.

Learning targets for students at the junior secondary level (Key Stage 3, Secondary 1 - 3) are to:

- develop curiosity and interest in science and appreciate the wonder of nature and the technological world;
- acquire basic scientific knowledge and concepts for living in and contributing to a scientific and technological world;
- develop science process skills to define problems, plan and design investigations to find solutions, conduct practical work, analyse and interpret the results, and present the findings;
- apply scientific knowledge, science process skills and relevant generic skills, to solve some daily life problems;
- use basic science language to communicate ideas;
- recognise the relationship between science, technology, society and environment, and develop an attitude for responsible citizenship;
- recognise the usefulness and limitations of science and the evolutionary nature of scientific knowledge;

- apply their understanding of science to maintain personal health and develop an awareness of safety issues in everyday life, understand the reasons behind, and take proper actions to avoid accidents and reduce risks; and
- consider the effects of human activities on the environment and act sensibly for sustainable development of the environment.

Learning targets for students at the senior secondary level, (Key Stage 4, Secondary 4 - 6) are to:

- sustain and further develop the interest and curiosity in science, as well as appreciate the wonder of nature and the technological world;
- have an understanding of the essential scientific knowledge and technological developments for living in and contributing towards a scientific and technological world;
- be able to construct and apply knowledge of science and master the science process skills;
- be able to integrate and apply knowledge and skills of science with other STEM-related disciplines, and develop an entrepreneurial spirit with positive values and attitudes;
- have the ability to make inquiries about science by employing scientific methods and solve daily life problems with innovative solutions;
- use the language of science to communicate ideas and express views on science-related/STEM-related issues;
- make informed judgements and decisions based on scientific evidence, and take responsible actions on safety issues;
- understand and evaluate the social, ethical, economic, environmental and technological implications of science, and develop an attitude for responsible citizenship;
- understand the different aspects of the nature of science and their implications, and also the limitations of science and technology; and
- understand the effects of human activities on the environment and be committed to act responsibly for the sustainable development of the world.

Learning Objectives

The learning objectives for the different strands at various stages of schooling are outlined below.

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

Scientific Investigation

- To show curiosity and interest in exploring the environment
- To observe phenomena in daily life
- To make simple measurements and grouping
- To record observations and make simple presentations
- To conduct simple scientific investigations

Life and Living

- To show love and care to living things and the environment
- To recognise the observable characteristics and needs of living things
- To recognise the different stages of growth and development in living things
- To recognise some body parts and their functions
- To develop healthy living habits
- To be aware of the interaction between living things and the environment
- To appreciate the existence of a variety of living things

The Material World

- To identify some common materials and their uses in daily life
- To identify the characteristics and changes of common materials using senses
- To design and make artifacts with common materials
- To show concern for the environment and be committed to environmental friendly practices in daily life

Energy and Change

- To recognise sources of energy and know their uses in daily life
- To recognise heat transfer and some related phenomena
- To understand the need for saving energy
- To describe energy use at home and in school

The Earth and Beyond

- To recognise and describe the basic patterns and objects in the sky
- To identify some features of weather changes
- To identify the features of day and night and how they are related to people's life patterns

Science, Technology, Society and Environment

- To be aware that science and technology are closely connected to activities in our daily life
- To show concern about the safety issues in relation to the use of science and technology
- To develop a caring attitude towards living things and the environment
- To recognise the proper ways of treating living things and the environment

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

Scientific Investigation

- To show curiosity and sustained interest in exploring science and technology
- To make observations, conduct measurements, record data and present findings
- To discuss observations and suggest simple interpretations
- To classify things according to common properties or features
- To design and conduct simple scientific investigations

Life and Living

- To respect and care for all living things and show concern for endangered species
- To recognise functions of major organs and systems of the body
- To be aware of the physical and emotional changes during puberty
- To show basic understanding of the life cycle of some living things
- To recognise ways of keeping our body healthy
- To recognise the interdependence of living things and their environment
- To appreciate the existence of a variety of living things in this world

The Material World

- To explore some physical properties of common materials in relation to their suitability for different purposes
- To recognise the use of some materials and their impacts on human and the environment
- To design and build models by using different materials
- To distinguish between reversible changes and those that cannot be easily reversed
- To make wise use of natural resources and develop a lifestyle that promotes sustainable development

Energy and Change

- To recognise some patterns or phenomena related to light, sound, electricity and object movement
- To recognise different forms of energy involved in energy change
- To use energy wisely and save energy in daily life
- To recognise the safety measures in using energy of different forms in daily life

The Earth and Beyond

- To recognise the Earth as a wealth of resources to fulfill our needs
- To identify and describe climate and seasonal changes and their effects on our life
- To illustrate some natural phenomena observable on the Earth caused by the movement of the Sun, the Earth and the Moon
- To appreciate the wonder of the Universe and the contributions of space exploration to everyday life

Science, Technology, Society and Environment

- To recognise the applications and effects of scientific and technological advances in daily life
- To appreciate some important people who have contributed to scientific and technological advancements of this world
- To show concern for the environment and climate changes, and recognise the importance of environmental conservation
- To recognise that the study of science and technology can both increase our understanding of the world and improve the quality of our life
- To identify the issues related to personal health and safety, and take appropriate actions to safeguard these in daily life

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

Scientific Investigation

- To identify problems for scientific investigations
- To identify variables for fair tests
- To plan, design and conduct scientific investigations
- To handle apparatus appropriately with necessary precautions
- To make detailed observations and record data
- To make use of multiple representations to present findings from scientific investigations
- To analyse data, draw conclusions and evaluate the investigation process

Life and Living

- To develop interest in studying living things, and show respect to all living things and the environment
- To appreciate the diversity of life and to understand the basic principles of classification systems
- To recognise that a cell is the basic unit of life
- To develop basic understanding of some of the life processes
- To recognise the processes related to reproduction and understand how a new life is born
- To recognise DNA as the genetic materials and the Book of Life
- To understand the importance and ways of maintaining body health
- To be aware of the impact of human activities on the environment and biodiversity

The Material World

- To recognise the physical and chemical properties of different materials
- To recognise the uses of different materials in relation to their structures and properties
- To understand the need to conserve natural resources
- To recognise some chemical changes and the materials involved

Energy and Change

- To compare the energy options available for particular uses in society
- To identify the processes of energy change and the conditions that may affect them
- To identify the forms and transformation of energy in a series of interactions
- To relate the observed changes in an energy receiver to the quantity of energy transferred
- To recognise the environmental effects due to energy production and consumption
- To recognise the need to conserve energy and act responsibly in daily life

The Earth and Beyond

- To recognise the useful sources of minerals and other natural resources available on the Earth
- To understand the meanings and relationship of distance, speed and time in describing motion
- To describe the effects of force on the motion of an object on the Earth

Science, Technology, Society and Environment

- To show basic understanding of the development of science and technology and its contribution to our life
- To recognise the effects of human activities on the environment, climate and natural resources on the Earth
- To act responsibly in conserving the environment for sustainable development
- To recognise the usefulness and limitations of science and technology

Learning Objectives at Key Stage 4 (Secondary 4 - 6)

Scientific Investigation

- To plan, design and conduct scientific investigations with multiple variables to control
- To conduct risk assessment in planning and designing investigations
- To make detailed observations and precise measurements by using appropriate equipment and instruments
- To analyse and interpret the data obtained, and draw conclusions for the investigations
- To evaluate the validity and reliability of the investigations and make suggestions for further improvement
- To write a full report for the scientific investigation

Life and Living

- To develop and maintain an interest in biology, and a respect of all living things and the environment
- To develop an understanding of evolution and the diversity of life
- To recognise the level of organisation of living organisms
- To develop an understanding of the essential life processes
- To understand the basic principles of genetics and biotechnology
- To be aware of the current advances of biotechnology and the potential impact on society
- To develop a commitment to promote personal and community health
- To develop an understanding of the interdependence of living things and their environment, and the impact of human activities on the environment and biodiversity

The Material World

- To understand the relationship between the uses of materials and their structures and properties
- To understand the interaction between different types of matter, and the relationship between matter and energy

- To investigate the processing of raw materials and the production of new materials
- To evaluate the use of materials from social, economic, environmental and technological perspectives

Energy and Change

- To describe systems that can transfer energy efficiently
- To explain the principles of energy input and output in different devices
- To apply ideas of conservation of energy and energy efficiency in relation to science and simple engineering applications
- To understand the environmental and economic effects of using different sources of energy
- To propose measures that can help to generate renewable energy and improve the efficiency of energy devices

The Earth and Beyond

- To explain some phenomena related to astronomy and space science
- To explain natural changes in the environment, such as seasonal and weather changes, climate changes, geological changes and natural disasters
- To describe the impact of human activities on the environment, such as exploitation of natural resources and environmental pollution, and suggest measures for conservation

Science, Technology, Society and Environment

- To master the skills in evaluating social, ethical, economic, environmental and technological implications of science and technology for sustainable development of the world
- To make informed judgements and decisions based on scientific evidence
- To understand the relation between the nature of science and the development of the society
- To make appropriate use of scientific knowledge and act responsibly as a local and global citizen

2.2.2 Generic Skills

Generic skills are fundamental in enabling students to learn how to learn. The following nine generic skills have been identified as essential for student learning for the 21st century in the school curriculum:

- Collaboration Skills
- Communication Skills
- Creativity
- Critical Thinking Skills
- Information technology Skills
- Mathematical Skills[3]
- Problem Solving Skills
- Self-learning Skills[3]
- Self-management Skills

Based on past experience of implementing the curriculum reform and in response to the dynamic changes in society and recent research, the nine generic skills are grouped in three clusters of related skills, namely Basic Skills, Thinking Skills and Personal and Social Skills, for better integrative understanding and application in a holistic manner (see the table below for details).

Table 2 Grouping of the Nine Generic Skills

Basic Skills	**Thinking Skills**	**Personal and Social Skills**
Communication Skills	Critical Thinking Skills	Self-management Skills
Mathematical Skills	Creativity	Self-learning Skills
Information Technology Skills	Problem Solving Skills	Collaboration Skills

[3] "Mathematical Skills" and "Self-learning Skills" have been referred to as "Numeracy Skills" and "Study Skills" respectively in earlier curriculum documents, such as *Learning to Learn: The Way Forward in Curriculum Development* (2001)

The Science Education KLA provides meaningful contexts for the development of generic skills, alongside science process skills, through appropriate activities for the learning and teaching of specific topics. Schools should plan science-related activities in a holistic manner for learning and teaching whereby students could apply and develop the generic/cluster of skills effectively.

Scientific investigations and experiments allow students to engage in hands-on and minds-on activities and to develop the skills associated with the practice of science. In the process, it is important for students to ask relevant questions, to pose and define problems, to formulate hypotheses, to plan what to and how to research, to predict outcomes, to conduct experiments, to interpret results, to draw conclusions and to suggest ideas for improvement. These experiences allow students to develop thinking skills for producing innovative ideas and solving problems, communication skills for presenting ideas, and mathematical skills for employing related concepts to tackle science-related problems. Students can also develop IT skills when making use of different IT platforms or devices for their investigations.

Project work, being either KLA/subject-based or cross-curricular in nature, provides an excellent context where students experience science as an interesting, challenging and dynamic study. It can help students integrate their everyday life experiences into their application of scientific knowledge, skills, and values and attitudes. During the learning process, students have to set goals, search for information from different sources, analyse and synthesise information, and communicate and present their ideas and findings. Besides, they may need to integrate and apply knowledge and skills of different STEM-related disciplines. Students develop collaboration skills and problem solving skills through project work. They also develop their critical thinking skills and creativity while solving problems. Other generic skills such as self-management and self-learning skills may also be developed in authentic context.

Group discussion, role-play and debate in science learning provide opportunities for students to interact with others, to express personal opinions and to exchange viewpoints from different perspectives. Students have to demonstrate their mastery of scientific language, and understanding of concepts through the process of researching and analysing information, organising and presenting ideas, and arguing and making judgements. They have to organise themselves and others to participate actively in group work. By reading, discussing, and role-playing controversial issues of science, students appreciate the nature of science in a societal context. In the reporting process, students learn to self-reflect and accept the viewpoints from others, as well as being objective in providing comments to others. Critical thinking skills, collaboration skills, communication skills, etc. could be nurtured throughout these learning processes.

2.2.3 Values and Attitudes

Values education is an essential and integral part of the school curriculum and is implemented through different components in KLAs, moral and civic education, cross-curricular learning opportunities and life-wide learning experiences. According to the revised Moral and Civic Education Curriculum Framework (2008), seven priority values and attitudes are identified to the uniqueness of Hong Kong as an international city in which both Chinese and Western cultures and values co-exist and interact. They are **perseverance**, **respect for others**, **responsibility, national identity**, **commitment**, **integrity**, and **care for others**. They are of vital importance for students' whole-person development to meet their own needs as well as those of society.

In the Science Education KLA, values education can be carried out through relevant topics and appropriate learning and teaching activities that help students apply and reflect on positive values and attitudes, or through different situations in which students are required to understand the issues from different perspectives, analyse them in a rational and objective manner, and adopt positive values and attitudes as the guiding principles for making judgements and decisions.

Cultivation of positive values and attitudes in the Science Education KLA

Positive values and attitudes are best developed through meaningful contexts along with the development of science process skills and generic skills. As examples, the learning and teaching of science and STEM-related activities could be permeated with the following values and attitudes:

- Curiosity
- Critical reflection
- Open-mindedness
- Respect for evidence
- Willingness to tolerate uncertainty
- Appropriately valuing the suggestions of others

- Caring for the living organisms and their environment
- Committed to sustainable development of the environment

Children are naturally born to be curious about daily life phenomena and are keen to explore things around them. Science teachers in both primary and secondary schools should maintain students' **curiosity** in natural phenomena so that they are eager to learn the content of the Science subjects, develop science process skills and see the connection between science and daily life. Furthermore, it is important to encourage students to plan, pose questions, inquire and explore ways to tackle the problems in the process of scientific investigations so as to satisfy their curiosity.

Innovative ideas are essential for the development of science and technology. People with innovative ideas and **perseverance** would appreciate the joy of discovery and derive satisfaction from intellectual growth. As science education promotes scientific literacy and encourages innovation through integration and application of knowledge and skills, teachers should help students understand the importance of relating daily life phenomena to scientific concepts and applications. Students should also learn to reflect on their handling of conflicting views from others.

Science is characterised as much by scepticism as by openness. For a new theory being developed, it is subject to challenges when experimental evidence emerges or inconsistency against existing scientific principles occurs. The theory has to go through a series of verifications and refutations prior to being widely accepted. Science education can help students strike a good balance between being **open-minded** and sceptical in thinking.

The advancement in science, technology and engineering is closely linked with the development of our society and the environment. Through science education, students can appreciate the importance of **sustainable development of the environment**, and learn to act responsibly in conserving the environment and to value biodiversity. They can also develop a caring attitude towards all living organisms.

The values and attitudes described above can be developed in the Science Education KLA through appropriate themes such as environmental conservation, stories about scientific inventions and explorations, scientific and technological development in ancient and modern China, etc.

2.2.4 Information Technology in Education (ITE)

Harnessing IT is the key to strengthening and facilitating learning and teaching in the 21st century. The four strategies on ITE launched by the EDB since the 1998/99 school year have brought about progressive advancement in making use of IT and e-learning resources to facilitate and enhance learning and teaching in primary and secondary schools. Owing to the unique nature of science, the linkage between science education and ITE is particularly strong. Over the years, most science teachers are keen supporters of IT and pioneers in exploring IT-enhanced pedagogies. They usually show a good grasp of the knowledge and skills in using online resources such as video clips and simulation software to facilitate students' understanding of abstract concepts, and utilising equipment such as data-loggers to record and collect data in experiments. By adopting teaching strategies such as "flipped classroom", some teachers are able to make better use of the time in class to cater for the needs and interests of their students, and develop pedagogies that are student-centred and effective for nurturing self-directed learning capabilities.

Technological Pedagogical Content Knowledge[4] (TPACK) is a framework that incorporate the kind of knowledge that teachers need to develop effective pedagogical practice in a technology-enhanced learning environment. The framework shows the interplay of three knowledge components: Content, Pedagogy and Technology. Effective integration of technology into the pedagogy for specific subject matter in science generally requires teachers' sensitivity to the dynamic and transactional relationship between these components of knowledge in relevant contexts.

Enhancement of the Wi-Fi infrastructure to cover all classrooms in public sector schools is one of the measures of the Fourth IT in Education Strategy (ITE4) which has been launched since 2015. Building on the successful experiences in using IT to facilitate various aspects of learning, teaching and assessment, schools are now better equipped for more extensive use of e-learning. With the increasing number of e-textbooks in the market and abundant e-resources such as mobile apps, use of mobile computing devices for learning anytime and anywhere becomes feasible and convenient. Therefore, ITE has been incorporated into the Science Education KLA curriculum framework to highlight its importance in unleashing the learning power of students in the years to come. To be specific, in the context of science education,

[4] www.tpack.org

emphasis will be made on further promotion of e-learning inside and outside the classroom, with a view to strengthening students' capabilities for self-directed learning, problem solving, creativity and innovativeness. While ITE is advocated, students should also learn to be ethical users of IT. To empower students to pursue whole-person development and lifelong learning, teachers should master their repertoire in e-learning, develop information literacy among students and promote assessment for/as learning with the effective use of IT in science education.

2.2.5 Language across the Curriculum (LaC)

Literacy refers to the ability to read and write effectively to achieve the desired goals or outcomes and develop one's knowledge and potential. At the school level, adequate literacy is developed on the two KLAs of Chinese and English Language Education. It is essential that literacy be also developed in different KLAs which provide contexts for students to apply their literacy skills to construct knowledge and to facilitate their development into lifelong learners.

With the rapid development of IT and the social media, literacy has taken on a new meaning. Students need to be equipped with new literacy skills to process and create multimodal texts in which messages are conveyed through different forms (e.g. images, animations and sounds).

The Science Education KLA provides authentic contexts for students to apply their literacy skills. The Language across the Curriculum (LaC) approach, which integrates language learning and content learning, can be adopted for students who may learn science through Chinese or English to explore knowledge and develop language skills in a comprehensive and integrative manner. While Chinese/English teachers focus on helping students master the accurate use of the language (e.g. vocabulary and grammar) as well as recognising the importance of coherence, cohesion and appropriacy in texts, Science teachers can facilitate the transfer of the Chinese or English knowledge and skills by emphasising the use of relevant genres for presenting the subject content during the learning and teaching process, and providing opportunities for students to apply relevant Chinese/English language knowledge and skills to demonstrate their understanding of the science content through completing the Science Education KLA-based assignments or tasks.

Science teachers can collaborate with the Chinese/English teachers to facilitate LaC through:

- identifying the entry points, setting realistic goals and drawing up a plan or schedule of work to facilitate transfer of Chinese/English language knowledge and relevant language skills;
- developing learning, teaching and assessment materials and activities that connect students' learning experiences;
- identifying a common topic between the Science and Chinese/English Language subjects for students to read about and discuss, and assigning learning activities or tasks outside classroom to broaden students' learning experiences;
- exposing students to the text types or genres commonly found in the Science Education KLA (e.g. procedural accounts); and
- teaching language features and rhetorical functions specific to the Science Education KLA (e.g. comparing and contrasting, giving explanations) explicitly to facilitate the completion of science tasks.

Some strategies/tasks that can enhance students' reading and writing competence in science are as follows:

	Strategies/Tasks
Reading (Reading to learn)	• Using graphical organisers • Unpacking and packing science ideas and language focus • Reading science news, magazines, fictions, stories of great scientists, etc.
Writing (Writing to learn)	• Writing laboratory safety rules • Writing experimental procedures • Describing observations • Giving a full account of experimental results • Writing investigation reports • Writing science stories, learning journals, etc.

Table 3 Strategies/Tasks for Enhancing Students' Reading and Writing Competence

2.3 Curriculum and Subject Organisations

Subjects of the Science Education KLA at the primary, junior secondary and senior secondary levels are as follows:

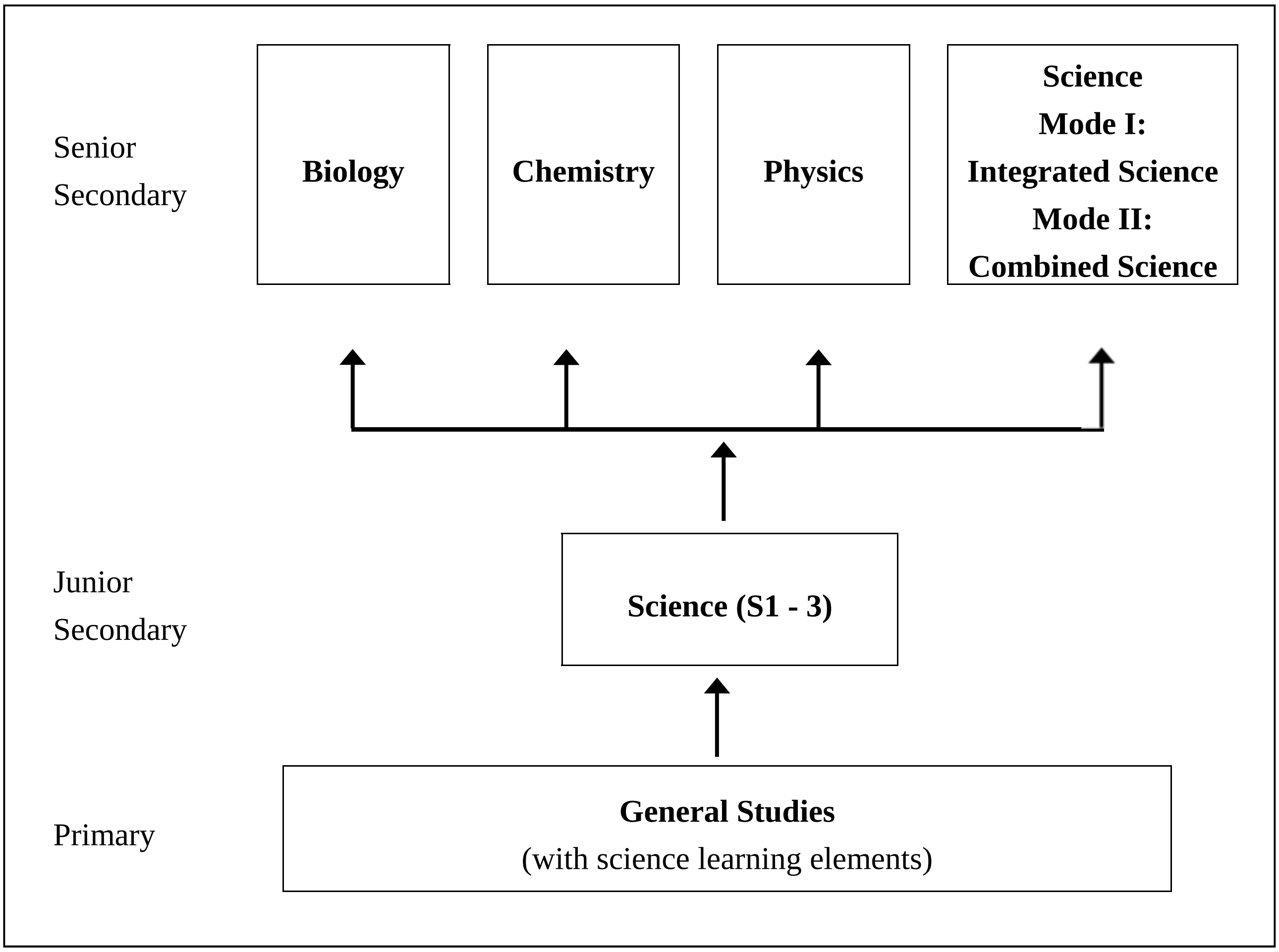


Figure 2.2

2.3.1 At the Primary Level

For the primary level, major updates to the primary General Studies (GS) curriculum include putting more emphasis on the relevance of science and technology to daily life (e.g. low carbon living, global warming) in the learning contents, enhancing basic science process skills, including observing, measuring, classifying and communicating, in science investigations (e.g. fair tests) to strengthen the interface between the primary and junior secondary levels, and enriching the learning and teaching activities related to the application of science and technology in solving daily life problems (e.g. energy use in daily life, the use of simple machines).

2.3.2 At the Junior Secondary Level

The Science (S1 - 3) curriculum continues to emphasise scientific investigations and include the *Core* and *Extension* parts to cater for students of different abilities and learning needs. The curriculum aims to develop a solid foundation in science among students at the junior secondary level. While developing students' scientific literacy, there is equal emphasis on the subject knowledge and relevant skills including hands-on skills. Major updates include renewing the learning contents to keep students abreast of the rapid development of science and technology, introducing unifying concepts to enhance students' understanding of the connections and overarching coherence across different science disciplines, strengthening students' science process skills and enriching the learning and teaching activities. Systems and organisation, evidence and models, change and constancy, as well as form and function are the unifying concepts introduced. On the other hand, the updated curriculum facilitates students to proceed more smoothly to the senior secondary level in learning science. Schools may refer to the recommendations given in the *Supplement to the Science Education KLA Guide: Science (S1 - 3)* (2017) for the development of their Science curriculum for Key Stage 3.

2.3.3 At the Senior Secondary Level

At the senior secondary level, a flexible and diversified science curriculum is offered to suit the needs of students with different interests and aptitudes. Since the implementation of the senior secondary curriculum in 2009, four science elective subjects are offered for students' selection, namely Biology, Chemistry, Physics and Science (Mode I: Integrated Science; Mode II: Combined Science). Building on the science curriculum at the junior secondary level, they are of the same academic rigour. These elective subjects aim at further enhancing the scientific literacy of students and pave way for their further studies and future careers. The elective subject curricula bear the same features of the Science Education curriculum framework with emphases on scientific investigation and STSE connections. On top of the Compulsory Part, Elective Parts are available in each of the elective curricula, to cater for the needs of students with different interests and aspirations.

- Students who show great interest in science and intend to pursue their studies or careers in science-related or STEM-related fields may select Biology, Chemistry and Physics.

- Students may also select a specialised subject of Biology, Chemistry or Physics and at the same time study parts of the other two subjects by a combined approach, so as to acquire more comprehensive knowledge in science. The three possible combinations are as follows:
    - Biology + Combined Science (Physics, Chemistry)
    - Chemistry + Combined Science (Biology, Physics)
    - Physics + Combined Science (Chemistry, Biology)

- Students who have diverse interest and wish to take up only one subject in the Science Education KLA may opt for Integrated Science. The curriculum adopts an interdisciplinary approach in the learning and teaching of science. It provides students with a comprehensive and balanced learning experience in different disciplines of science.

The senior secondary level is an important stage before students proceed to tertiary education or join the work force. Elective subjects in the senior secondary Science Education curriculum aim to provide a firm foundation for students to further their studies of a wide range of academic, professional and vocational education programmes in the tertiary institutions, or enter a wide spectrum of science-related/STEM-related careers when they leave schools. Therefore, schools should offer students sufficient information about the nature of different Science elective subjects and related opportunities when they graduate from school, and encourage them to choose the elective(s) that best fit(s) their interests, aptitudes and career aspirations. Appropriate guidance and support (e.g. talk on life planning, choice of senior secondary elective subjects) should be provided to help students make informed choices.

The latest version of the Curriculum and Assessment Guides for Biology, Chemistry and Physics, Integrated Science and Combined Science are available at the following website of the EDB:

www.edb.gov.hk/en/curriculum-development/kla/science-edu/index.html

2.4 Smooth Transition between the Primary and Junior Secondary Levels

The study of the primary GS curriculum enables students to acquire the fundamental knowledge of the three KLAs, namely Science Education, Technology Education and Personal, Social and Humanities Education, as well as to develop generic skills, and positive values and attitudes. The science learning elements of the curriculum help arouse students' curiosity and interest in inquiring scientific phenomena in daily life. The basic science foundation developed among students will foster their learning of science at the secondary level.

The Science (S1 - 3) curriculum is developed as a continuation of the science learning elements in the primary GS curriculum. It serves to further develop students' curiosity and interest in science, as well as their scientific knowledge and science process skills. To facilitate a smooth transition between the primary and secondary levels, it is essential for teachers to cover all relevant core elements in the GS curriculum at the primary level. Opportunities should also be arranged to develop their science process skills, creativity, innovativeness and problem solving skills.

When planning the primary GS curriculum, teachers need to ensure the vertical continuity across different key stages, and that students will have a firm grasp of the knowledge and skills necessary for a smooth progression from one key stage to another.

2.5 Smooth Transition between the Junior and Senior Secondary Levels

A holistic approach should be adopted by schools in planning the school Science curriculum in secondary schools with due consideration of the interface between the junior and senior secondary levels. Attention should be made to address the vertical continuity and lateral coherence of the Science curriculum to cater for the needs of students of different interests, capabilities and aspirations. Reference should be made to the learning targets and objectives of the Science Education curriculum for various key stages as listed in Section 2.2.1 of this chapter, as well as the Curriculum and Assessment Guides for Biology, Chemistry, Physics, Integrated Science and Combined Science for the senior secondary level.

For smooth transition from the junior secondary to the senior secondary levels, teachers need to complete the Core part of the Science (S1 - 3) curriculum in the first place. Besides the Core part, teachers may select materials from the Extension part to cater for the needs, interests and abilities of their students. Where appropriate, teachers might include some enrichment topics in the school Science curriculum to extend students' learning experiences to different science disciplines. Apart from knowledge, sufficient learning opportunities should be arranged for students to develop their skills, in particular science process skills, and positive values and attitudes towards science.

Chapter 3
Curriculum Planning

Chapter 3 Curriculum Planning

3.1 A Balanced Curriculum

Science education plays a significant role in the whole-person development of students. All students are entitled to science education and should be provided with appropriate learning opportunities to develop scientific knowledge and skills, and the ability to integrate and apply knowledge and skills across disciplines. In view of this, schools should adopt whole-school curriculum planning to ensure that appropriate resources, including time, human and financial resources are deployed for the development of a broad and balanced school curriculum of which science education is an integral part.

3.2 Central Curriculum and School Curriculum Development

This Guide sets the direction for the development of the Science Education curriculum from Primary 1 to Secondary 6. It provides a central curriculum for the Science Education KLA in the form of an open and flexible framework comprising strands, learning targets and objectives, and major learning contents. Schools should refer to the recommendations highlighted in this Guide to ensure that students acquire opportunities of learning science. This Guide should not be regarded as a prescribed uniform syllabus for all schools and students. With reference to the central curriculum framework, a Science curriculum should be developed by individual schools with due consideration of the school contexts.

In the development of a school Science curriculum, schools should note the aims of the Science Education KLA as well as the learning targets and objectives to be achieved by students at different stages of schooling. Reference should also be made to relevant curriculum documents on the learning, teaching and assessment of the subjects of the Science Education KLA at different key stages. Feasible measures may include varying the choice and sequence of the learning contents and contexts, providing options for students, and adopting learning, teaching and assessment strategies that best suit the learning needs of students.

3.2.1 Holistic Curriculum Development in the Science Education KLA

Holistic curriculum development is recommended to ensure vertical continuity and lateral coherence in the planning of a school Science curriculum. A coherent Science curriculum with smooth transition and progression between key stages enables students to establish a solid foundation in science and proceed smoothly from one key stage to another. Schools have to take into consideration the interests and abilities of their students and the expertise of their teachers when setting the goals and devising the plans for their Science curriculum development. During the planning process, schools need to consider flexible use of the lesson time allocated as well as the resources available according to individual contexts. Due attention should be drawn to the curriculum emphases when designing science-related or STEM-related learning and teaching activities for students. The process of Planning-Implementation-Evaluation (P-I-E) that schools are familiar with can be adopted.

All Science teachers should get involved in the development of the school Science curriculum. While the Science Education KLA co-ordinators or panel chairpersons take the lead in co-ordinating the above development process, all Science teachers have roles to play in planning, implementing and evaluating the Science curriculum at the year or class level. For cross-KLA activities, teachers of the Science Education KLA need to collaborate with their counterparts of other related KLAs in planning and organising relevant activities. Laboratory technicians are also helpful in supporting the learning and teaching of science, and organising STEM-related learning activities. With extensive involvement of teachers and laboratory technicians in the process, a collaborative culture could be developed within and across KLAs. Close collaboration among teachers of the STEM-related disciplines can enhance professionalism, thus producing a synergy effect and maximising benefits to students.

Figure 3.1 illustrates how to develop a school Science curriculum with full consideration of the major factors, and eventually arrive at a curriculum decision that can benefit student learning.

Holistic Curriculum Development in the Science Education KLA

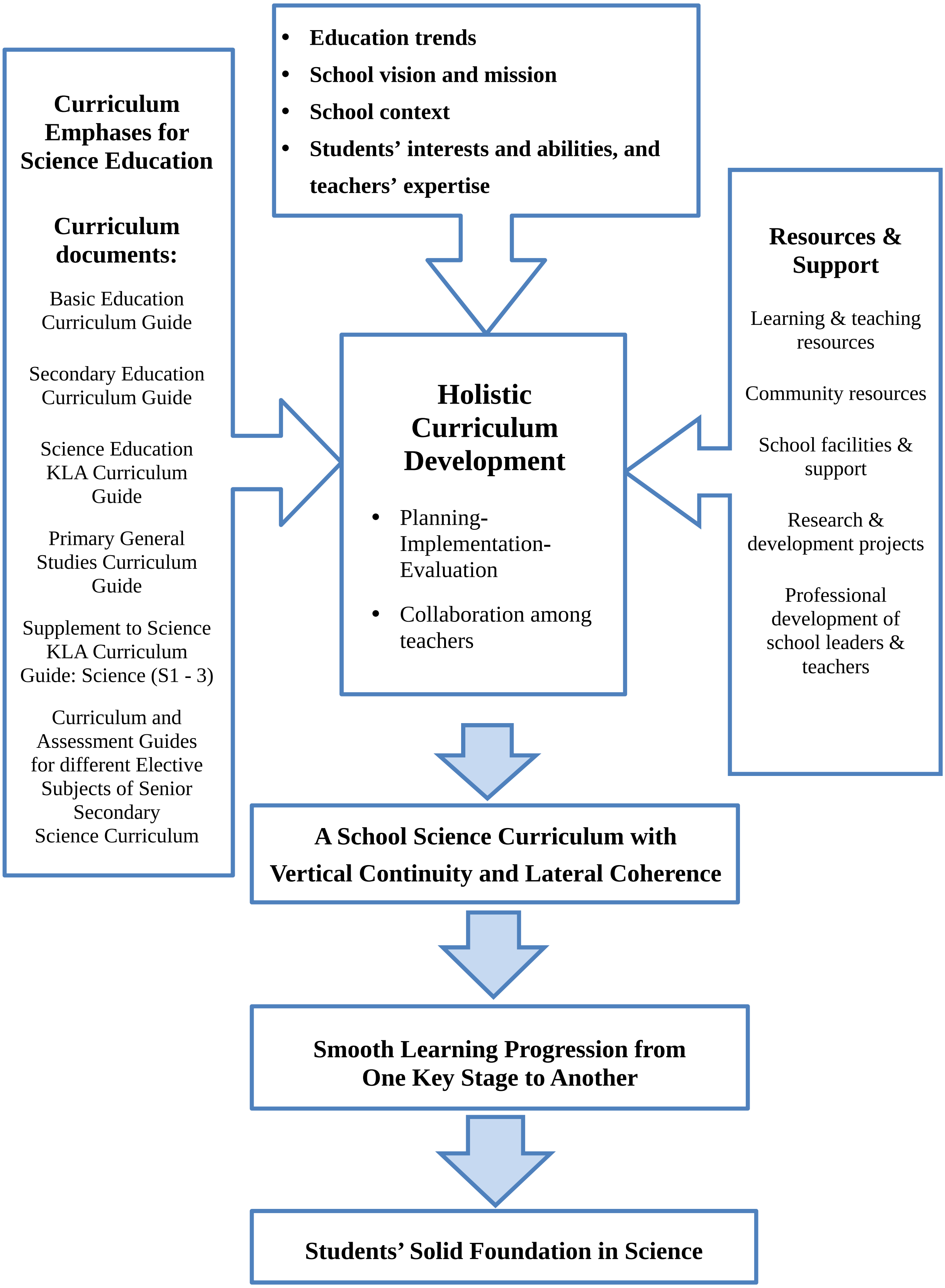


Figure 3.1

3.2.2 At the Primary Level

Science learning elements are included in the different strands of the primary GS curriculum. The proposed content of the GS curriculum is divided into the Core and Extension parts. The Core contains the basic components of the GS curriculum and helps students master the basic knowledge, skills and attitudes. It constitutes approximately 80% of the lesson time allocated to GS. The Extension provides diversified learning experiences geared to more in-depth study on particular topics in the Core and occupies the remaining 20% of the lesson time allocated to GS (see Section 2.4.2.2 of the ***Basic Education Curriculum Guide (P1 - 6)*** (2014) for details).

3.2.3 At the Junior Secondary Level

The Core and Extension parts are also available in the Science (S1 - 3) curriculum. The Core covers the basic scientific knowledge and skills that all students should learn, and helps develop their scientific literacy. By concentrating on the Core, it is hoped that more time is available for students to understand the basic scientific concepts and skills. The Extension constitutes further learning of scientific knowledge on wider scope or at a deeper level. Some topics in the Extension are more demanding and more suitable for students who aim to pursue further studies in the senior secondary science curricula. Teachers should note that the level of attainment for each topic within the Extension could vary from school to school and also from class to class. There is flexibility for teachers to choose topics from the Extension to suit the needs and abilities of their students, hence providing challenges students who are more able or with strong interest in science to develop their potential.

3.2.4 At the Senior Secondary Level

The Science curriculum at the senior secondary level is built on the knowledge foundation developed at the junior secondary level. The curriculum of each subject has been specially designed to strike a balance between breadth and depth, between scientific theories and practical applications, and also between core and extended learning. In addition to the compulsory part, the elective part, which serves to extend the knowledge and skills of students, is provided to suit the needs and interests of different students. For some subjects, the Core and Extension parts are also available in the compulsory part to embrace learner diversity. The curriculum of each senior secondary Science subject emphasises the development of scientific inquiry and lesson time is recommended to be reserved for scientific investigations.

Depending upon the school contexts, it is desirable for schools to offer choices of science elective subjects and consider the provision of different subject combinations to cater for the needs and aspirations of their senior secondary students.

For effective holistic curriculum planning, there should be measures to develop in students a solid foundation in science to facilitate their smooth progression from one key stage to another. Curriculum emphases of the Science Education KLA and MRE such as strengthening science process skills, promoting STEM education, adopting e-learning to promote self-directed learning of science may be included in the development of the school Science curriculum. While planning the learning and teaching activities, due consideration should also be given to assessment practices, resources and support, cross-KLA collaboration and professional development of teachers which are crucial factors for successful implementation of the school Science curriculum. The activities that schools may organise for students or teachers will depend on individual school contexts and their development priorities.

Reflective Questions

1. How can teachers arouse primary students' interest in learning science, build up their scientific knowledge and develop their science process skills effectively?

Points for consideration

- To nurture students' curiosity and arouse their interest in learning science, teachers should connect students' learning experiences to daily life. Students should be motivated and guided to have an increased awareness of the natural and human world and a keen interest in observing their surroundings, to pose questions and to acquire a basic understanding of some simple natural phenomena.
- To develop students' knowledge and skills in science and technology, it is important to engage students in activities which involve different processes, such as observations, exploration, identification and classification. Where appropriate, teachers may also provide learning opportunities for students to realise the role and importance of mathematics in science and technology.

- Students can learn more effectively in authentic contexts. To enrich the learning experiences of students, teachers should engage them in life-wide learning activities that take place outside the classroom.

2. Is it appropriate for teachers to introduce the subject contents of the senior secondary Science curricula to junior secondary students?
3. How important is the learning of the Science (S1 - 3) curriculum for further studies at the senior secondary level?

Points for consideration

- Every junior secondary student is entitled to learn the Core part of the Science (S1 - 3) curriculum. The Core ensures that students acquire a solid foundation in science at the junior secondary level. Schools have to complete, at least, the Core part within the lesson time allocated to Science Education KLA. Subject to the needs, interests and abilities of students, schools may include additional learning materials of other science-related or STEM-related disciplines to enrich students' learning.

- In the planning of the school curriculum, any additional materials for junior secondary students have to be commensurate with their age and conducive to their cognitive development. The breadth and depth of the school junior secondary Science curriculum have to match the general ability of the students. Due care has to be taken to avoid reducing students' interest and motivation in learning science, should teachers try to introduce the subject contents of the senior secondary Science curricula to junior secondary students.

- The study of the Science (S1 - 3) curriculum helps students build up a solid foundation in science, in terms of the subject knowledge and skills, generic skills, and positive values and attitudes. A good foundation in science will facilitate their progression to learning the senior secondary science elective subjects. Besides, it is essential for the development of cross-disciplinary knowledge and skills among students at the junior secondary level. No matter which subjects choose for their future studies, a firm knowledge base in science will enable them to integrate and apply knowledge and skills and develop interest in science for further studies and future careers.

3.3 Cross-KLA Collaboration and Linkage with Liberal Studies

3.3.1 Strengthening Students' Ability to Integrate and Apply Knowledge and Skills through Collaboration among the Science, Technology and Mathematics Education KLAs

The Science, Technology and Mathematics Education KLAs have an important role to play in the promotion of STEM education. Schools can strengthen students' ability to integrate and apply knowledge and skills, as well as their development of positive values and attitudes towards STEM-related issues, through:

- providing a favourable environment with ample opportunities for students to integrate and apply knowledge and skills of different disciplines during the process of learning;
- holistic curriculum planning with due consideration of the different scenarios provided to students to integrate and apply knowledge and skills across disciplines;
- making use of KLA-based and cross-disciplinary learning activities of different natures (such as project learning, problem-based learning and mathematical modelling) to provide meaningful contexts that are closely related to daily life to engage students in problem solving. The activities may include scientific investigations, design and make tasks, etc. that can foster integration and application of knowledge and skills of different disciplines;
- encouraging and supporting students to participate in, wherever appropriate, STEM-related competitions and other fun-filled learning activities organised by different local and overseas organisations as well as those organised by local museums and professional bodies on a regular basis; and
- promoting collaboration among teachers at the school level in planning and organising cross-disciplinary learning activities.

3.3.2 Linkage with Liberal Studies

Building a solid foundation in science at the junior secondary level not only enhances the scientific literacy of students and helps them become responsible citizens of this scientific and technological world, but also facilitates their learning of different science elective subjects and Liberal Studies (LS) of the senior secondary curriculum.

Science education is an essential part of the school junior secondary curriculum. With a solid foundation in science, students are able to integrate science concepts with their knowledge from other KLAs/subjects, and make connections between their learning experiences of different subject disciplines. This will enable students to think from multiple perspectives and develop the ability which is conducive to their study of LS at the senior secondary level. The scientific habits of mind will also allow students to develop the ability to sensibly comment on issues related to science, technology and engineering from the social, environmental and ethical perspectives. Students can also learn to solve problems with innovativeness, and make informed decisions that are based on evidence. Therefore, the study of the Science (S1 - 3) curriculum at the junior secondary level is essential in building up cross-disciplinary knowledge which can facilitate students' progression to study LS at the senior secondary level.

3.3.3 Linkage with Other KLAs

When planning the school Science curriculum, teachers should help students connect their learning experiences of the Science Education KLA and with those of STEM-related or other KLAs/subjects. Cross-curricular activities could be organised to enhance the effectiveness in learning science. Some examples of collaboration between the Science Education KLA and other KLAs to enhance students' learning are provided below for reference.

Table 4 Linkage of Science Education KLA with other KLAs

KLA	Examples
Chinese and English Language Education	• Promoting Reading across the Curriculum (RaC), e.g. arranging students to read science fiction, stories of scientific discoveries and famous scientists to stimulate their interest in science and STEM-related fields • Engaging students in drama activities, debates, etc. on themes related to science and technology • Designing writing tasks (e.g. writing articles, journals and advertisements) on issues related to the advancement in science and technology

KLA	Examples
Personal, Social & Humanities Education	• Engaging students in cross-curricular activities such as those related to Health Education, Sex Education, Environmental Education, and Moral and Civic Education • Discussing with students scientific, technological and engineering issues from the social, environmental, economic and ethical perspectives, and the importance of an entrepreneurial spirit in further studies and future careers in STEM-related fields
Arts Education	• Providing opportunities for students to appreciate the beauty of the natural world, the natural phenomena, and man-made engineering products
Physical Education	• Engaging students in cross-curricular activities, such as sports science related activities, and how scientific knowledge and technology is used to improve the performance in sports

3.4 Promoting Values Education

Being an essential part of the school curriculum for whole-person development, values education is broadly delivered through moral and civic education, and cross-curricular and life-wide learning activities. Schools need to plan and strengthen values education in accordance with the school mission and contexts.

Similar to other KLAs, the Science Education KLA can help cultivate students' positive values and attitudes. Values education can be carried out through relevant topics in the different strands of the Science Education KLA as well as learning and teaching activities to deepen students' understanding of the priority values and attitudes and to nurture other values and attitudes. Students should be guided to apply and reflect on the positive values and attitudes in different situations when making informed judgements on issues related to science. Various learning activities (e.g. issue-based learning) provide contexts for students to tackle authentic issues through which students could cultivate positive values and attitudes.

Schools should regularly review the learning elements of values education in the Science Education KLA together with those of other KLAs, life-wide learning, Other Learning Experiences (for SS students only), moral and civic education, and school ethos, etc. This could be done by mapping the learning elements with the set of values and attitudes for incorporation into the school curriculum (see Appendix 2 of the SECG Booklet 2 for details). In the development of the school Science curriculum, schools have to take into account a range of learning objectives contributing to the development of positive values and attitudes at different key stages. During holistic curriculum planning, Science teachers should infuse relevant elements of values education in the learning activities conducted inside and outside the classroom with a view to cultivating students' positive values and attitudes.

3.5 Strengthening e-Learning and Information Literacy

Information literacy (IL) refers to the ability and attitude that would lead to an effective and ethical use of information. It aims to develop students' abilities to (i) identify the need for information; (ii) locate, evaluate, extract, organise and present information; (iii) create new ideas; (iv) cope with the dynamics in our information world; and (v) use information ethically and refrain from immoral practices such as cyber bullying, infringing intellectual property rights. Learning activities such as project learning and e-learning provide opportunities for students to develop and apply IL.

The learning of science usually involves IL so the Science Education KLA has a role to play in developing students' IL. For example, scientific investigation and STEM-related project learning often require data collection, organisation, analysis, interpretation and reporting, which involve essential skills related to IL. Infusion of IL in the primary General Studies and the secondary Science subjects enhances students' ability to apply knowledge and skills, enable them to gain more benefits in learning science, and equip them better to live in the contemporary world as informed and responsible citizens. Students should also develop themselves to be ethical users of IT.

With the launching of ITE4 since 2015, all public sector schools have acquired mobile computing devices and are equipped with access to Wi-Fi in all classrooms. Moreover, a good variety of e-resources is available to facilitate learning, teaching and assessment of different KLAs/subjects at different levels. Most science teachers are keen in adopting e-learning. For example, students are provided with opportunities to use electronic devices such as data-loggers to collect and record data in experiments, and to use mobile devices in field work or learning activities conducted inside and outside schools. With enhancement of the Wi-Fi infrastructure supported by ITE4, both students and teachers are conveniently connected to the Internet and can gain access to a wide range of e-resources including e-textbooks, and e-assessment tools. Real-life issues can be easily integrated into the school Science curriculum to facilitate the design of deep learning tasks and provide meaningful and authentic science learning experiences. Schools have to further strengthen Science teachers' repertoire in e-learning strategies in order to unleash the power of our students to learn and excel. Science teachers should explore and adopt e-learning pedagogies more widely, and make effective use of e-assessment to enhance student learning.

Schools have to incorporate e-learning strategies into the holistic planning and implementation of the Science curriculum with a view to promoting self-directed learning, developing IL, embracing learner diversity and promoting assessment for and as learning. Due consideration has to be given to critical issues in promoting e-learning, such as conditions of IT equipment, availability of relevant e-resources, pedagogies adopted by teachers, professional development of teachers and current assessment practice. e-Learning activities for science should be arranged, where appropriate, to develop students' self-directed learning habits, collaborative learning skills, problem solving skills, creativity, computational thinking, etc. While knowledge and skills related to e-learning are emphasised on one hand, attention should also be appropriately drawn to strengthening the values and attitudes of students in using IT on the other, particularly the ethical use of IT. Elements of IL need to be infused in the planning and implementation of the e-learning activities where appropriate.

3.6 Planning of Learning Time

Schools should refer to the *Basic Education Curriculum Guide (Primary 1 – 6)* (2014) and the *Secondary Education Curriculum Guide (Secondary 1 – 6)* (2017) in planning the lesson time allocated to the General Studies curriculum at the primary level and the different Science subject curricula at the junior and senior secondary levels.

A summary of the suggested allocation of lesson time is provided below:

- At the primary level, schools can allocate 12% to 15% of the total lesson time to the General Studies for each key stage from Primary 1 to 6 (KS1 – 2).
- At the junior secondary level, the Science (S1 – 3) curriculum accounts for 10% to 15% of the total lesson time over a course of three years in KS3.
- At the senior secondary level, each of the Science elective subjects of the senior secondary curriculum accounts for 10% to 15% of the total lesson time over a course of three years in KS4.

Schools may vary the percentage of time allocation for different year levels of a key stage as long as the total lesson time falls within the recommended range.

Schools are reminded that 19% and 8% of the total lesson time is reserved for schools' flexible use at the primary level and the junior secondary level respectively. Flexibility is provided for schools to deploy the flexible time to conduct cross-curricular activities, such as those for values education for students' whole-person development. As for the senior secondary level, 10% to 15% of the time allocation is set aside for Other Learning Experiences (OLE). Schools should give due consideration to the overall planning and co-ordination among different KLAs and subjects with flexibility to organise OLE during and outside school hours.

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Chapter 4

Learning and Teaching

Chapter 4 Learning and Teaching

Learning and teaching are interactive processes, which involve complex dynamic relationships among students, teachers, learning contexts and learning environments. A good understanding of the aims and the learning targets and objectives of the Science Education curriculum as well as how students learn enables teachers to provide interesting and effective learning experiences for their students. This chapter discusses different pedagogical approaches and highlights the importance of adopting appropriate learning and teaching strategies and setting meaningful homework to support and enhance the learning and teaching of science and to embrace learner diversity. There are also suggestions on the use of the updated Four Key Tasks, STEM-related activities and life-wide learning activities to foster students' whole-person development and promote the MRE of the ongoing renewal of the school curriculum.

Schools may refer to Chapter 4 of the *Basic Education Curriculum Guide (Primary 1 - 6)* (2014) and Booklet 3 of the *Secondary Education Curriculum Guide (Secondary 1 - 6)* (2017) for more ideas on learning and teaching approaches and strategies.

4.1 Guiding Principles

The learning and teaching of science should build on the strengths of schools' improvement in the adoption of various teaching approaches and in the assessment of student achievement brought by the education reform over the past decade. In line with the vision of developing students to be self-directed and lifelong learners, it is necessary for Science teachers to help students build up deep learning competencies in order to develop the ability to acquire, integrate and apply knowledge and skills to solve authentic or real-life problems.

It is a natural path for students to progress from rote learning of selected contents for the mastery of foundation knowledge to developing capabilities for learning, creating, connecting and applying the knowledge and skills acquired proactively and purposefully in authentic contexts. It is thus crucial for Science teachers to adopt pedagogical approaches to help students achieve deep learning and develop ownership in learning. A variety of learning experiences should be provided for students to collaborate with others, construct their own meaning, plan, manage and make choices and decisions about their learning. When students are engaged in these types of learning activities, they could develop a deeper understanding of newly acquired knowledge and skills, and have a greater sense of ownership of their learning.

Many scientific, technological and engineering advancements are cross-disciplinary in nature. It is essential to enhance students' interest and develop in them a strong knowledge base in science, technology and mathematics by promoting STEM education. Some learning elements of technology, engineering and mathematics could be included in the learning and teaching of science to develop students' ability to integrate and apply knowledge and skills across disciplines.

4.1.1 Roles of Science Teachers

In order to create a dynamic and engaging learning environment for the 21st century learners, Science teachers need to perform multiple roles in motivating, facilitating and enabling learning in varied learning contexts to cater for students' diverse learning needs and to achieve the specific targets set for different key stages of learning. Below is a table showing the different roles Science teachers may need to play.

Table 5 Roles of Science Teachers

Roles of Teachers	Actions (examples)
Transmitters of knowledge	Give lectures, provide and present information.
Facilitators	Discuss with students and provide guidance in the process.
Resource persons	Advise on sources of information and build networks for learning.
Counsellors	Provide advice on study methods and pathways.
Assessors	Inform students of their strengths and weaknesses to make plans for the next stage of learning.
Leaders	Take the lead in motivating student learning.
Co-learners	Learn alongside students

On top of a good understanding of the aims and learning targets and objectives of the Science Education curriculum, teachers should use adequate learning and teaching strategies according to the topics or skills to be learned as well as the interests and abilities of students. Teachers should also set the expected learning outcomes in consideration of the abilities, learning styles, interests and prior knowledge of the students, as well as the resources and lesson time available.

In practice, Science teachers may need to play more than one role at a time. For example, during the process of project learning or scientific investigation, Science teachers may need to act as resource persons who provide reference materials and specify the scope of the project or investigation. They may also need to perform the roles of facilitators and counsellors, especially when students encounter difficulties during the process. As the product of project work or investigation is usually open-ended, teachers may need to be co-learners who learn with students, respect different views from students and keep themselves updated of the latest development in the particular field of science being studied by students.

Self-directed learning is the goal as well as the process to enhance students' readiness and capacity to plan, manage and improve their own learning. To develop students' self-directed learning capabilities as well as a deeper understanding of scientific knowledge and skills, teachers should provide opportunities for students to set their learning targets, plan, monitor, and manage their learning. Students should be encouraged to make choices of activities and set their own goals; to be involved in planning the learning process; to reflect and review on their learning experience; and to seek help from others if necessary.

Science teachers are held responsible for taking all the necessary safety precautions for all science learning activities. When arranging practical work for students, teachers should provide proper supervision to ensure that safety measures are observed. Risk assessments are needed for activities, such as student experiments, teacher demonstrations and outdoor activities, in which hazards may be involved. With the assistance of laboratory technicians, teachers are advised to try out novel experiments beforehand so that any potential risks can be identified before performing them in class. The Safety Handbook for General Studies for Primary School (2011)[5] and the Safety in Science Laboratories (2013)[6] are good references for safety management in primary and secondary schools respectively.

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5 www.edb.gov.hk/attachment/en/curriculum-development/cross-kla-studies/gs-primary/safety%20handbook-eng.pdf

6 cd1.edb.hkedcity.net/cd/science/laboratory/safety/SafetyHandbook2013_English.pdf

4.1.2 Roles of Students

In a rapidly changing world and an information-intensive environment, students need to build up self-directed and lifelong learning capabilities that enable them to have an ever-increasing capacity to learn, make sense of new information, construct knowledge, work with others and realise their own potential.

Self-directed learners can optimise and maximise their learning through the development of learning partnerships that engage them in purposeful collaboration and exploration with their peers and teachers, which also contributes to deep and meaningful learning. Learning is an interactive activity and knowledge construction is a social process. A learning partnership can facilitate student learning, in that students can be entrusted with taking an active role in stimulating each other to work towards a common learning target, sharing work and ideas, giving feedback and collaboratively exploring different approaches to achieving the shared target.

Depending on their abilities and learning styles, students can perform different roles in a learning partnership. Students with good inter-personal and collaboration skills can assume a more prominent role in leading group discussions and those who excel in critical thinking can play a key role in examining the accuracy of given statements and formulating standpoints. As experienced learners, teachers can provide support and guidance, and enable the learning partnership to flourish when needed. Partnership brings more interactions, so each student learns to appreciate, comment on and value the views of others, gains greater involvement in learning and becomes more motivated, and takes part in the co-construction of knowledge.

Learning science involves making inquiries. The problems to be investigated can come from teachers or students. Students should be allowed to shape the questions and take steps towards the solution of the problem, so that the investigations become their own tasks. Students could learn how to evaluate their progress, reflect on what they have learned, and decide what they want to pursue in the next step. In this way, students could learn to manage their own learning process and develop a sense of responsibility for their own learning.

4.2 Approaches to Learning and Teaching

Owing to students' diverse needs and specific targets in different learning contexts, teachers need to have a thorough understanding of different pedagogical approaches to designing and providing meaningful learning experiences. In general, pedagogical approaches can be categorised in accordance with the following three notions of learning and teaching: learning as a product of direct instruction, learning and teaching as a process of inquiry, and co-construction. The pedagogical approaches premised on these notions of learning are not mutually exclusive. Different pedagogical approaches could be used in different parts of the learning and teaching process. For example, in a Biology lesson designed as an inquiry-based activity related to the prevention of diseases in Hong Kong, there could be direct instruction on the part by the teacher explaining the background of the issue and the associated key terms. In the course of inquiry, students could be encouraged to take part in a collaborative task to identify ways for disease prevention and to evaluate the feasibility of the proposed solutions. The key principle for choosing suitable pedagogical approaches is "fitness for purpose". The above-mentioned approaches can complement one another, and no single pedagogical approach can contribute to all learning objectives and cater for students' diverse needs.

Direct Instruction

This approach concerns explicit teaching of the knowledge and skills of the Science subjects. Teachers introduce new concepts and demonstrate new skills. Modelling and thinking-aloud are the crucial elements in the learning and teaching process. Teachers pose questions, check for understanding, and draw connections between key concepts while making the thinking process visible to students, so that students can learn to apply the same thinking strategy to other topics and problems of similar nature.

Direct instruction, in general, involves the following major stages in the learning and teaching of science:

Table 6 Stages of Direct Instruction

Stage	Purpose
1. Introduction of learning objectives and expected learning outcomes • At the beginning of a science lesson, the teacher shares the learning objectives and expected learning outcomes with students.	• Help students learn better as they have a clear purpose of learning and understand what is expected of them.
2. Teacher presentation and modelling, supplemented with questioning and checking for understanding • During the teaching process, the teacher presents the target science concepts or science process skills in a progressive manner, starting with input (e.g. through lecture supplemented with videos or other resource materials), moving on to teacher modelling, checking for understanding and re-teaching the target concepts or skills if necessary.	• Use various science learning activities and resource materials to assist explanation and provide demonstrations to students. For example, the teacher highlights certain parts of a video programme to illustrate the key concepts. • Make the thinking process visible for students to observe and practise the strategies.
3. Guided practices • The teacher guides students to work through learning activities and experience how scientific knowledge and skills can be applied to accomplish a given task. • For example, the teacher provides guidance and helps students conduct science experiments or solve science problems.	• Observe student learning and provide instant feedback. If some students cannot master the knowledge or skills required for the task, the teacher immediately offers hints, scaffolding, clarifications or further explanations.

Stage	Purpose
4. Application of what has been learned through independent practices • At the end of the lesson, the teacher recaps and clarifies the key concepts of science just covered and then gives assignments to students for application and consolidation of what has been learned.	• Provide different and yet relevant situations for students to apply the knowledge and skills acquired to consolidate their learning.

Inquiry Learning

Inquiry learning emphasises the development of thinking skills through posing challenging questions for students, and engaging them in investigation, discussion, reflection and making connections in learning. In the Science classroom, students could develop their understanding of phenomena/issues in daily life through scientific investigations in which they identify the problems, set the questions, formulate and test hypotheses, plan the investigation procedures, gather and analyse data, and draw conclusions. Science learning activities in the process of inquiry may involve the following steps:

1. Ask – ask questions related to a given daily life phenomenon, issue or problem;
2. Hypothesise – formulate hypothesis;
3. Experiment or survey – design and perform the experiment or survey, collect, organise and analyse relevant information and experimental result;
4. Conclude – draw conclusions on findings; and
5. Reflect – evaluate and reflect on the inquiry process, and propose alternative ways to study the issues further.

At any stages of the inquiry process, students can always go back to an earlier step when they are not fully ready for the tasks ahead.

Co-construction

Co-construction empowers students to generate knowledge, meaning and understanding as they work collaboratively with teachers, their peers and the wider community in the form of learning partnerships. This view of learning mirrors the functioning of research and adult learning in the scientific community or other professional fields where members of the learning community bring in their existing knowledge, learning experiences and multiple perspectives when exploring a given issue.

Learning activities or tasks that support co-construction are usually open-ended and authentic in nature. Teachers and students are performing the roles of facilitators of learning and empowered learners respectively in this co-learning process. To facilitate collaboration and discussion, teachers create a supportive and stimulating learning environment for students to engage in knowledge-building discourse. Instead of determining what exact information or material is to be studied, teachers help students select and distinguish relevant information and resources, provide input or instruction where appropriate, and guide students through the thinking process.

4.3 Effective Learning and Teaching Strategies

To enhance the learning of science and to make science interesting, relevant and important to students, learning and teaching strategies such as practical work, investigation, discussion, role-play, debate, context-based learning, problem-based learning and project learning could be adopted. When selecting a pedagogical strategy, teachers should note the importance of the alignment between the curriculum, pedagogy and assessment, and attention needs to be given to the following:

- how to build on students' prior knowledge and experiences;
- whether the lesson or series of lessons covers adequately in terms of breadth and depth, and what is worth learning as set out in the curriculum; and
- what specific learning, teaching and assessment strategies should be used to facilitate, monitor, inform and improve learning.

Some useful strategies and examples of activities for the learning and teaching of science are listed below for teachers' reference:

a) Practical Work

Science subjects are practical subjects. It is essential for students to gain personal experience of science through activities involving doing and finding out. Students should be aware of the importance of being careful and accurate when doing practical work, making observations and measurements. Practical activities should be integrated into the learning of scientific principles as far as possible, so that students can associate the findings of the experiments with the science ideas or concepts they have learned. At the beginning, teachers should provide sufficient guidance and support (e.g. procedural guidelines and data tables) for students. As students gain sufficient knowledge and skills related to the practical work, the amount of guidance and support could be gradually reduced.

Examples

General Studies (P1 - 6)

Practical work can be arranged for the topic of "Light and Shadows" to explore the relationship between the position of light source and the shape and size of the shadow. During the experiment, students can work in groups to observe the shadow of an object as they change the position of the light source. Students may be asked to record the size and shape of the shadow when the light source lights up the object at different heights and angles. Science process skills such as observing, measuring and recording need to be applied during the investigation. As an extended activity, students may further observe different objects outside the classroom and see the shadows of trees, houses, cars, etc. under the sunlight. Students may be asked to record the shapes and sizes of the shadows casted by their teammates in the morning, at noon and in the late afternoon when the sun is at different positions in the sky. Through this activity, students could acquire better understanding of the relationship between the position of a light source and its effect on the shadow cast.

Biology (S4 - 6)

Practical work can be arranged for the topic of "Digestion and Absorption" to simulate the digestion and absorption of food in the alimentary canal using dialysis tubing. Students are provided with the opportunity to apply the practical skills on preparing experimental setup and conducting relevant tests for food substances. Through this activity, students' understanding of the digestion and absorption process in the alimentary canal is enhanced.

b) Scientific Investigation

Scientific investigations involve observing phenomena, defining problems, formulating hypotheses, designing and conducting investigations, and interpreting results. Investigative activities are not just for verification purposes. They also allow students to understand the process of science, including how to clarify questions, how to design an experiment, how to record and interpret data, and how to communicate the knowledge generated.

When arranging investigative activities, teachers should exercise professional judgement to arrange investigative tasks which are suitable for their students. Simple investigative tasks with clearly-defined problems can be arranged for junior form students or less able students, whereas complex and ill-defined problems could be given to senior form students or students with higher abilities. It is desirable to expose students to different types of investigations so that they will progress from "cook-book" type experiments to more open-ended investigations which involve finding the answers to questions they have formulated by themselves. Besides the science process skills, group investigative activities could enhance students' generic skills such as communication skills, mathematical skills, IT skills, collaboration skills, creativity, critical thinking skills and problem solving skills.

Example

Physics (S4 - 6)

An investigative activity, called a "Solar cooker competition", may be organised for students when the topic of "Transfer Processes" is taught. Students are requested to apply their knowledge of conduction, convection and radiation, as well as the skills acquired in various topics of the curriculum, to design and conduct a simple investigation on energy transfer by constructing a solar cooker. Students can investigate the effects of different materials and designs on the rate of temperature rise in the cooker. Students need to draft a brief plan in small groups at the beginning and engage in discussion. They can then construct the solar cookers in groups and measure the temperatures of the cookers under direct sunlight. They may be asked to discuss and choose appropriate instruments for measuring the temperature. For more in-depth investigation, students may try to determine the power rating of the solar cooker designed and relate it to the solar constant obtained from the literature.

c) Problem-based Learning

Problem-based learning (PBL) is an instructional method driven by a problem. PBL, which is commonly adopted in many subject disciplines, is usually used in professional training courses when the participants are given the kind of authentic problems they will face at work. The problems are open-ended, often based on real-life situations and usually ill-defined with no quick and easy solution. In the process, students may acquire new knowledge and skills, and integrate them with what they have learned previously to solve the problems. Students are required to understand and define the problem, discover what they need to know to tackle it, generate alternatives; develop and test solutions, and justify their suggested solutions. Depending on the abilities of students, teachers should set problems with different levels of complexity, hints or thought-provoking questions to guide them. Thus, teachers need to assume the roles of facilitators, resource persons and observers. Students are motivated by actively engaging themselves in the learning process and taking responsibility for their own learning.

Apart from motivating students to develop a deeper understanding of the topic, PBL also encourages them to think critically and creatively, and to solve problems collaboratively in science-related contexts. At the same time, their capability for self-directed learning is also enhanced in the process.

Example
Chemistry (S4 - 6)
The students are asked to imagine themselves as a chemist working for a coffee company. The company plans to launch the world's first self-heating coffee can. The students are asked to design a can which could heat the coffee contained inside to 60^{o}C within three minutes and maintain the temperature for 30 minutes. The can should be convenient to carry and easy to use, and the coffee is to be served straight out of the can. The following questions could be raised to help students analyse the problem:

- What is the volume of the coffee can?
- How much heat energy is required to heat up the coffee to the required temperature?
- Which chemicals can react to produce a steady supply of heat?
- What is the amount of each type of chemical to be used?
- Is the product safe for use by the consumers?

Students can test their proposed solutions to the problem in many ways, such as in a real laboratory or in a virtual environment.

d) Context-based Learning

Learning is most effective when it is built upon the existing knowledge of students. Learning accessible to students through a real-life context will increase their interest and enhance the learning effectiveness. Context-based learning highlights the relevance of science to students' daily life and can be employed to enhance their awareness of the interconnections among science, technology, society and the environment. When students have learned the concepts effectively and confidently in one scenario, they can transfer their concepts, knowledge and skills to other contexts.

Example

Physics (S4 - 6)

Modern cars have crumple zones which crumple easily in collisions, thus helping to protect the passengers in a car accident. In this activity, students are asked to design and build a crumple zone for a toy car, and then test their design using a data logger. They are encouraged to design their own tests and choose the construction materials. Information on the webpage of Contextual Physics (www.hk-phy.org/contextual/) is a helpful resource for students' reference when conducting this activity.

e) Group Discussion, Role Play and Debate

Group discussions, role plays and debates provide opportunities for students to interact with others, express their opinions and exchange viewpoints. They are effective ways to motivate and engage students actively in learning, and to develop their generic skills such as collaboration, communication, critical thinking and problem solving skills. These learning activities involve students in the processes of searching for and analysing information, organising and presenting ideas in a clear and logical manner, arguing and making judgements.

Group discussions and debates are particularly suitable for dealing with controversial issues. Students may be first given some background information on a specific case and allowed time for individual thinking. They are then divided into groups to discuss and exchange views. Students should be encouraged to interact with their peers, while the teacher acts as a facilitator who guides students to work in the right direction, and provides timely feedback on their performance. Some environmental and ethical issues provide meaningful contexts for students to explore conflicting viewpoints through role plays. In this way, students can explore the experience and views of different characters in a given scenario, and widen their perspectives on the topic being studied.

Examples

Science (S1 - 3)

- A debate on the use of nuclear energy.

Biology (S4 - 6)

- A debate on the dilemma between urbanisation, industrialisation and conservation.
- A debate on the issues related to genetically modified food, animal and plant cloning, Human Genome Project, gene therapy and stem cell therapy.

f) Searching for and Presenting Information

In this information era, students can gather information from various sources such as books, newspapers, magazines, scientific publications, digital media and the Internet. It is important for students to develop IL so that the information collected from various sources can be organised, analysed and presented properly, and that the information can be assimilated into knowledge and drawn upon for making informed judgements. Teachers should encourage students to conduct information search in activities such as group discussion, PBL and project learning. It is desirable for students to gain experience of how to work with information in diverse situations, especially with incomplete and vague information from sources that might be doubtful. Sometimes, students may be overwhelmed with information, and it is important for them to be properly guided so that they can learn how to extract relevant information according to their needs and to use information ethically.

Example

General Studies (P4 - 6)

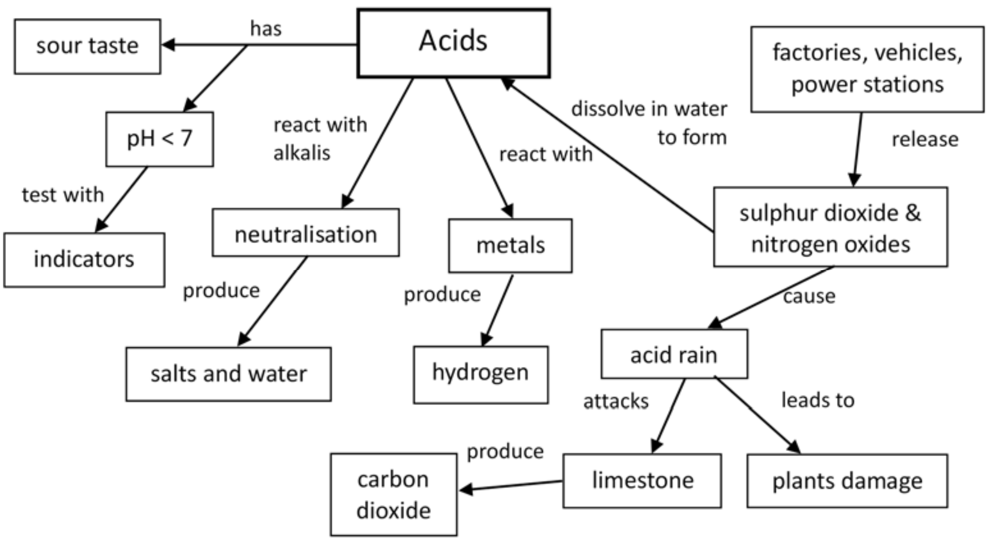
Vertebrates can be classified into five different groups according to their features, namely, fishes, amphibians, reptiles, birds and mammals. Students may work in groups to search for information about these five groups of vertebrates from various sources and organise their corresponding features (e.g. in table form). As an extension activity, students may search for the classification of some other animals such as dolphins and penguins, and present information about their classification. Through this activity, students could understand the criteria for the classification of living things.

g) Concept Map

Concept maps are graphical tools for organising and presenting knowledge, and help students describe the links between concepts. They can be used as tools to generate ideas, communicate complex ideas, aid learning by explicitly integrating new and old knowledge, assess understanding or diagnose misconceptions. Students should be encouraged to construct concept maps to strengthen their understanding of a topic, and subsequently refine the concept maps according to teachers' comments, peer review and self-evaluation in the course of learning. To familiarise students with this way of representing information, they may first be asked to add the links between concepts or label the links on a partially prepared concept map. Apart from constructing concept maps by hand, many computer programs are available to help create and revise concept maps easily.

Example

Science (S1 - 3)



Concept map on "Acids"

h) Design and Make

Design and make activities are often adopted in the learning and teaching of science. Besides making science lessons more interesting to students, design and make activities can help students connect scientific knowledge and skills with their daily life. Students are provided with a real-life problem to solve by designing and making an artefact which can be a model, a tool or a product related to science. Students can incorporate a scientific investigation in the design process to identify factors associated with the improvement of their design or product with controlled experiments. Through hands-on and minds-on activities, students will not only enhance their knowledge and understanding of science, but also develop their innovativeness and problem solving skills.

Examples

General Studies (P4 - 6)

- Design and make a toy car, powered by elastic bands.
  Features:
  - applying concepts of force and energy;
  - applying science process skills (e.g. observing and designing an investigation);
  - developing collaborative problem solving skills and creativity; and
  - developing the ability to integrate and apply the knowledge and skills of science, technology and mathematics.

Science (S1 - 3)

- Design and make a water rocket or a balloon car that can travel the longest distance.
- Design and make a game for the school fun fair by using reflection of light.

4.4 Approaches to Organising Learning Activities on STEM Education

STEM-related learning activities should bridge across the curricula of the KLAs of Science, Technology and Mathematics Education to enhance students' interest and innovativeness, and to develop their ability to integrate and apply knowledge and skills within and across KLAs. When planning and designing these learning activities, Science teachers should collaborate with teachers of the Technology and Mathematics Education KLAs to facilitate students' integration and application of knowledge and skills. Depending on the school contexts, students' interests and abilities, and teachers' expertise, two different approaches are recommended to organise STEM-related learning activities.

Table 7 Approaches to organise STEM-related activities

Approach One	*Learning activities based on topics of a KLA for students to integrate relevant learning elements from other KLAs* In this approach, learning activities based on a particular topic of a subject of the Science Education KLA are designed for students to draw on relevant learning elements from the Technology and Mathematics Education KLAs for the integration and application of the knowledge and skills across disciplines. For example, in the science topic of "Force and Motion", students study the scientific theories and grasp the knowledge related to the launching of a rocket. Through a variety of activities, related learning elements from the Mathematics and Technology Education KLAs, such as computation, algebra, design and make, and choice of materials for model making, could be incorporated and used to enrich the learning activities and also the learning experience of students.

Approach Two	*<u>Projects for students to integrate relevant learning elements from different KLAs</u>* In this approach, project learning or other STEM-related learning activities are arranged for students to integrate the related learning elements from the Science, Technology and Mathematics Education KLAs. Students are assigned an authentic problem to tackle. During the process, students need to confront the issues, and to solve daily life problems with practical solutions and innovative designs. Relevant learning elements and experiences from different KLAs have to be brought in by students themselves. To solve the problem, they would need to integrate the knowledge and skills they have learned from different subject disciplines and apply them flexibly in a real context.

Diagrams illustrating these two approaches to organising learning activities on STEM education are available in Appendix 2.

PBL, context-based learning and project learning are deemed suitable learning and teaching strategies for organising learning and teaching activities on STEM education. The uses of authentic contexts and daily life problems could highlight the relevance and importance of science to students, and enhance students' awareness of the interconnections among science, technology, engineering, society and the environment.

4.5 Four Key Tasks for Promoting Learning to Learn

In order to help students develop independent learning capabilities, the four key tasks of Moral and Civic Education, Reading to Learn, Project Learning, Information Technology (IT) for Interactive Learning have been recommended for schools' implementation of the curriculum reform since 2001. In the ongoing curriculum renewal, these tasks are updated as **Moral and Civic Education: Towards Values Education, Reading to Learn: Towards Reading across the Curriculum, Project Learning: Towards Integrating and Applying Knowledge and Skills across Disciplines,** and **Information Technology (IT) for Interactive Learning: Towards Self-directed Learning**. The updated key tasks are applicable in the Science

Education KLA to enliven learning and teaching, and to help students achieve whole-person development and become self-directed learners.

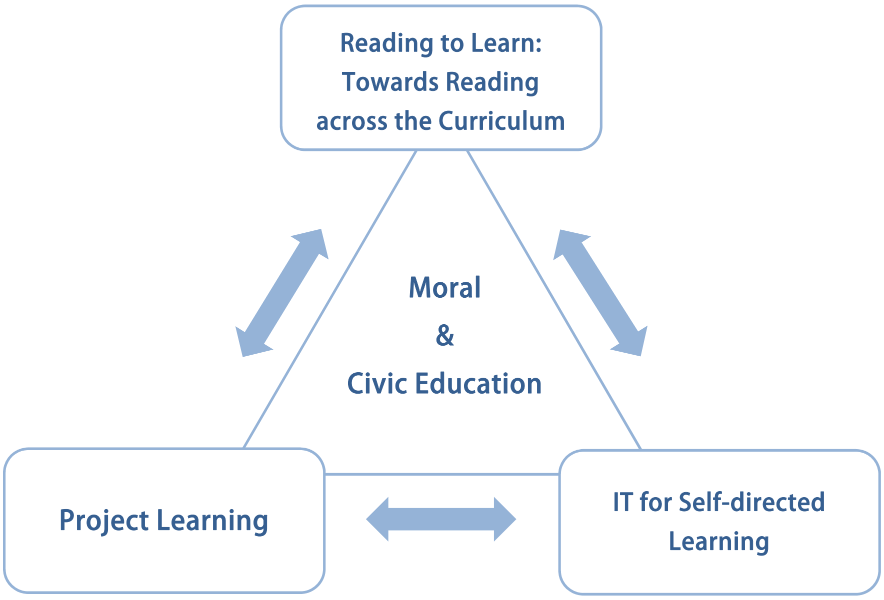


Figure 4.1 Four Key Tasks

4.5.1 Moral and Civic Education: Towards Values Education

Learning opportunities inside and outside the science classroom should continue to be provided to nurture the seven priority values and attitudes among students. Teachers can make use of events relevant to students' daily life to cultivate positive values and attitudes. The following learning and teaching activities illustrate how the learning element of values education can be incorporated into the Science Education curriculum:

- Activities such as visiting residential care homes for the elderly or hospitals can be organised. In these activities, students could observe the needs of the elderly or the disabled, and apply what they have learned in science to design and make artefacts to help them, e.g. a toilet tissue dispenser which can be operated single-handedly. Values such as "care for others" and "sensitivity" can thus be developed in a science context.
- Teachers can invite speakers from The Family Planning Association of Hong Kong to give talks to students when teaching the topic of "Human Reproduction" in the Science (S1 - 3) curriculum. Students will recognise the tie between relationship and responsibility and be able to make judgement about appropriate behaviour in a relationship. At the same time, students will appreciate the value

and sanctity of life, understand the importance and responsibilities of parenthood, and develop a positive attitude towards life.

Other issues with conflicting values, such as “sustainable development” and “climate changes” could be used as learning contexts for the development and application of generic skills, and fostering of positive values and attitudes.

4.5.2 Reading to Learn: Towards Reading across the Curriculum

“Reading to Learn” has been an essential key task for enhancing students’ learning capacity leading to whole-person development and lifelong learning. During the process of reading to learn, students are able to draw upon their prior knowledge, learning experiences and world knowledge so as to gain an in-depth understanding of a text and construct meaning. To support a whole-school approach to “Reading to Learn”, students should also have access to a wide range of books, newspapers, magazines, encyclopedias and other e-reading materials. Science teachers can prepare a suggested list of reading materials and design related reading tasks for their students. Through reading stories about famous scientists, the history of science and news/articles about the latest development in different branches of science, students will understand how scientists looked for evidence and inferred from experimental results. This helps students appreciate the achievements of scientists and engineers, as well as develop their curiosity, scepticism and perseverance in learning science.

- A “Science/STEM Corner” can be set up in the classroom or the science laboratory to display interesting science/STEM-related articles from various sources to raise students’ awareness of current issues related to different scientific disciplines. Students can also be asked to write short summaries of these articles and include personal reflections on the issues concerned.
- With the advancement of IT and the improvement of IT infrastructure in schools, teachers could make use of the school e-learning platform to assign reading tasks to students. Students could also make use of the platform to share their comments and reviews of books and articles with their peers.

4.5.3 Project Learning: Towards Integrating and Applying Knowledge and Skills across Disciplines

Project learning is an effective learning and teaching strategy to promote students' learning to learn capabilities for self-directed and lifelong learning. Over the years, science projects are usually assigned to students at different levels. Science teachers have acquired a lot of experience in arranging project learning for their students.

Project learning is inquiry in nature. It usually starts with an inquiry question or a problem, and involves students in working in groups or individually to plan, read, gather information, draw conclusions and make recommendations over a period of time. Project learning could help students develop all the nine generic skills.

Both the process and the product of project learning are important. Project learning adds values to the acquisition of subject knowledge through providing alternative learning experiences, which allow students to have more space for engaging in self-directed learning. Therefore, teachers should pay attention to "what students learn" and "how students learn" when designing project learning activities for them. Science projects may be arranged in the form of scientific investigations, research proposals, surveys, design and make of artefacts for specific purposes, etc. Depending on the nature, science projects could be used for a variety of education purposes. Projects with investigative elements contribute towards the promotion of scientific inquiry. Projects that aim at solving everyday problems help to bring the relevancy of the science ideas that students learn in class to daily life. Projects involving the Science, Mathematics and Technology Education KLAs could help students integrate and apply knowledge and skills across the STEM-related disciplines.

4.5.4 Information Technology (IT) for Interactive Learning: Towards Self-directed Learning

Learning is a knowledge acquisition and construction process which usually involves interactions among teachers, students and learning resources. Self-directed learning generally refers to the ability to take initiative and responsibility for learning. Self-directed learners are able to identify their learning needs, formulate goals and choose resources and strategies for learning.

Self-directed learning is enhanced with the support of IT as students can assess their own learning, and learning can take place at any time, in any place and through any means. Self-directed learning in the context of using IT generally manifests the following characteristics: learners' control, learners' self-management, personal autonomy, and tendency of self-learning, i.e. the independent pursuit of learning outside formal settings.

IT connects students to the vast network of information and is generally regarded as an effective tool that can facilitate the development of self-directed learning. In line with ITE4, schools can make good use of e-learning, which refers to an open and flexible learning mode involving the use of electronic media such as digital resources and communication tools to achieve the learning objectives, to develop students' self-directed learning abilities and habits, and also to nurture their IL. With appropriate uses of IT, Science teachers can design deep learning tasks to help students draw upon their prior knowledge across disciplines, discover and master scientific knowledge, and make connection between science learning and the real world. Therefore, teachers should develop a repertoire whereby e-learning may help to enhance, modify and complement some existing learning and teaching strategies or develop new e-learning pedagogies to suit the school contexts.

As specific examples, e-learning can be adopted in the Science Education KLA by:

- using the Internet as a resource of data and information;
- using interactive online materials to support the learning of specific topics at students' own pace;
- watching animations to help visualise natural phenomena and processes, and grasp abstract concepts, e.g. the motion of particles in a liquid as temperature changes;

- using interactive simulations to learn different concepts through manipulation of different simulated objects through self-directed learning;
- using video-imaging devices for experiments or demonstrations, in order to observe/investigate some processes in greater details, e.g. the Brownian motion;
- using a data-logger to conduct experiments; (A data-logger is an electronic device which could save time for collecting and recording data. It could also allow latching of fast-changing data and auto-recording of data that vary slowly over time. For example, a data-logger with a position sensor can be used to study the motion of a ball falling under the action of gravity with graphical presentation of the data collected.);
- introducing the flipped classroom in which students watch video clips uploaded by teachers to the school intranet or the Internet before attending a lesson so that teachers could spare the lesson time for more engaging learning activities such as group discussion and collaborative problem solving;
- using mobile computing devices such as smartphones and tablet computers installed with apps for interactive learning inside and outside the classroom, e.g. using locational-based applications to extend science learning beyond the classroom;
- using Learning Management System (LMS) for discussion, sharing of learning experiences, access to resources and support, collaborative learning, recording learning progress and self-reflection; and
- utilising online assessment tools, such as multiple-choice question banks and instant response devices, for students to acquire prompt feedback on their work, and for teachers to render appropriate follow-up actions/support to students if necessary.

While the use of IT facilitates e-learning and other interactive activities, offers space for developing students' scientific thinking, creativity and problem solving skills, and fosters the development of self-directed learning, teachers need to exercise their professional judgement on the appropriate use of IT and ensure that the students are provided with sufficient opportunity for hands-on experiments to develop their science process skills. Efforts should also be devoted to nurture students to be ethical and responsible users of IT.

4.6 Life-wide Learning

Life-wide Learning (LWL) refers to student learning in real contexts and authentic settings to achieve targets that are more difficult to attain through classroom learning. It helps students achieve the aims of whole-person development and enables them to develop the lifelong learning capabilities that are needed in our ever-changing society.

To extend students' learning experiences, teachers could incorporate LWL into the learning and teaching of science by arranging visits to the following places:

- The Hong Kong Wetland Park and the Kadoorie Farm & Botanic Garden, which provide guided educational visits for students to appreciate the nature and to enhance their awareness of the need for environmental conservation;
- The Hong Kong Science Museum and The Hong Kong Space Museum, which provide comprehensive exhibits and interesting hands-on activities for students, who may acquire hands-on experiences in observation and data-recording through performing simple investigations;
- Health InfoWorld (the health promotion and publicity section of the Hong Kong Hospital Authority), which has built up good connections with various organisations in the health and medical fields and provides a wealth of resources for students on topics related to health; and
- Nature reserves, country parks, marine parks and other local habitats.

With community support, a wide range of learning opportunities is also available for students, e.g. science lectures, science invention competitions, science projects, science exhibitions, field trips, laboratory research and experiments.

4.7 Embracing for Learner Diversity

In every school, there are students with different learning styles, needs, interests and abilities. For effective learning and teaching, teachers should always attend to learner diversity and take appropriate actions to help students learn better. Teachers should equip themselves with a repertoire of strategies, such as flexible grouping, remedial and extension activities, and varying the curriculum contents, teaching strategies and assignments according to students' abilities, needs and interests. While ample support is given to the less able or unmotivated students, schools should also groom those with a special talent in science/STEM-related fields and develop their potential to the full.

The followings are some strategies that could be adopted to embrace learner diversity in the Science Education KLA:

a) Varying curriculum contents

The curriculum framework of the Science Education KLA, which is open and flexible, allows teachers to devise their own curriculum to meet the needs of their students. In the primary General Studies curriculum and the Science (S1 - 3) curriculum, Core and Extension parts are included to facilitate the design of appropriate learning experiences. The Core contains the basic scientific knowledge and skills that all students should master at the specific key stage of schooling. The Extension provides further learning of scientific knowledge and skills and includes more challenging activities for students with a stronger interest or higher ability in studying science and developing their potential. There is flexibility for teachers to choose topics from the Extension to suit the needs and abilities of students. For the senior secondary Physics, Chemistry, Biology and Science curricula, students could choose topics from the elective part based on their interests and the professional judgement of their teachers.

b) Employing a variety of learning and teaching strategies

Teachers should be flexible in their choice of learning, teaching and assessment strategies related to science education to maximise the learning effectiveness among students of different learning styles. Some students are visual learners, some are auditory learners, while some are kinesthetic learners. Teachers should adopt a range of presentation modes and vary their teaching strategies to address such differences. A variety of resource materials including textual, visual and audio materials may be used; and individual and group work should also be arranged to allow students to study and learn science in their preferred styles.

c) Adapting learning tasks for students with different abilities

The scale, nature and demand of learning tasks in science should be adjusted for students with different abilities. For capable students, teachers can design tasks which are challenging enough to maintain their motivation. For students who are less able, small and less demanding tasks can help them build up their capacity and confidence gradually. Teachers may, for example, break down a complicated scientific investigation into a series of simple ones. On the other hand, for the more able students, the scientific investigation can be made more demanding by including more variables and requiring the collection of more data or the adoption of more sophisticated instrumentation and skills.

d) Flexible grouping

Students can acquire mutual support when they work collaboratively to complete a learning task. Students of different abilities can be grouped together to facilitate sharing of knowledge and skills. Alternatively, students with similar ability can be grouped together to work on tasks of commensurate challenge to foster the development of a sense of success and confidence in learning.

e) Grooming students with special talents in science

Enrichment activities and additional challenging work should be given to students with special talents in science/STEM-related fields. For example, they can be allocated more demanding problems, be asked to define and then explore the problems by using information from a range of sources, and attempt to work on possible solutions. Students who master self-directed learning can be allowed to further pursue their interests by, for example, setting objectives for their own investigations. In addition, students with special talents in science/STEM-related fields should be encouraged to participate in science competitions (e.g. the Primary Science Project Exhibition, the Hong Kong Student Science Project Competition and the Physics Olympiad Competition), local/overseas learning programmes and research projects to further develop their potential.

4.8 Meaningful Homework

Regarding planning homework for students, it is the quality rather than the quantity that counts. Schools should refer to the EDB circular on "Guidelines on Homework and Tests", formulate the school homework policy, and allow space and time for students to participate in meaningful social and extra-curricular activities conducive to whole-person development.

Meaningful homework should help students construct knowledge, apply the knowledge and skills acquired, and develop deeper understanding of and make connections among the concepts learned. More precisely, science homework should be designed to:

- achieve the learning targets and objectives in the Science curriculum commensurate with students' learning progress;
- consolidate student learning;
- help students understand their own progress and identify areas for improvement;
- extend classroom learning and prepare students for new learning; and
- assess the knowledge acquired and also the skills, and values and attitudes developed.

4.8.1 Principles for Setting Meaningful Homework

Some science learning tasks are preferably carried out during school hours because of safety concerns (e.g. scientific investigations and experiments that require special equipment and apparatus). Some tasks can be assigned to students for completion at home for consolidating what has been covered in class, pre-lesson preparation or online extended learning. Common types of science homework assigned to students include multiple-choice questions, short questions, structured questions, experiment reports, reading science books and articles, group work requiring online collaboration, individual or group projects, writing essays and journals, and building science models. Teachers should refer to the following principles when setting science homework for students:

- Arrange different types of homework according to the learning and teaching approaches adopted.
- Design homework which can meet the needs, interests, and abilities of the students.
- Assign appropriate amount of homework with due consideration of the time and effort needed for each task. Homework should not overburden students, or be used as a punishment.
- Avoid mechanical repetition, like copying notes or vocabulary, which would reduce students' motivation in learning science.
- Assign both short-term and long-term assignments. Short-term assignments usually help students review and practise what has been covered in class or prepare for a new lesson. Long-term assignments such as science projects require students to plan their own pace of work, delve into issues that interest them, and integrate information, ideas and views.

- Consider the family/ethnic background of students when deciding on the types of homework to be assigned. This applies particularly to homework which involves the use of IT and project learning, of which students are required to purchase specific equipment/materials or pay for visits/excursions. Teachers should ensure that in the context of homework, no students are underprivileged due to their family/ethnic backgrounds.

4.8.2 Guidance and Feedback on Homework

To help students maximise their benefits from homework, appropriate guidance and timely feedback should be given to students as outlined below:

- Give clear instructions and guidelines on what is expected of students when assigning homework.
- Provide clues to students who might have difficulties in completing the task.
- Give concrete and positive feedback to students, so that they could review and improve their learning. For example, if an appropriate on-line platform is used, feedback could be timely given to students at different stages of project learning.
- Arrange opportunities, where appropriate, for students to provide feedback on their peers' homework. Through giving feedback, students could also engage in self-reflection and assess their own performance.

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Chapter 5
Assessment

Chapter 5 Assessment

5.1 Guiding Principles

5.1.1 From Curriculum and Pedagogy to Assessment

Assessment is an integral part of the curriculum, pedagogy and assessment cycle. It involves collecting evidence about student learning, interpreting information and making judgements about students' performance with a view to providing feedback to students, teachers, schools, parents and other stakeholders. The purposes of assessment are manifold, but the prime purpose should always be for facilitating and improving student learning.

5.1.2 Roles of Assessment

The roles of assessment for different stakeholders can be summarised as follows:

- For students to:
  - understand the objectives of their learning and their progression towards achieving these objectives;
  - understand their strengths and weaknesses in learning and how they can improve and self-regulate their work so as to move to the next stage of learning; and
  - identify their own learning needs and ways to improve their learning strategies, and eventually become self-directed learners.
- For teachers and schools to:
  - understand the strengths and weaknesses of their students in learning;
  - guide students to improve their learning by providing quality feedback;
  - evaluate the curriculum design and learning and teaching practices, and make appropriate adjustment to enhance learning and teaching effectiveness; and
  - understand the needs and abilities of their students in learning to better embrace learner diversity and to guide them towards self-directed learning.
- For parents to:
  - understand the strengths and weaknesses of their children in learning;
  - co-operate with schools in preparing their children for future learning; and
  - set reasonable expectations on their children.

- For other stakeholders (including tertiary institutions, government, employers, etc.) to:
  - recognise the standard of students in specific areas;
  - facilitate the selection of students for particular learning pathways; and
  - examine the standards being achieved and make judgements about the quality of education to be provided.

5.2 Formative and Summative Assessments

Formative and summative assessments are both valued in science education. From the student-centred perspective, assessment activities have moved away from simply allowing students to demonstrate learning outcomes or achievements to integrating with learning and teaching.

5.2.1 Formative Assessment

Formative assessment serves two major purposes, namely assessment for learning and assessment as learning.

Assessment for Learning integrates assessment into learning and teaching. It can be achieved by assessing students on a continuous basis with different methods such as classroom observation, class activities, assignments, projects, practical tests and written quizzes. It aims at identifying students' strengths and weaknesses and providing quality feedback for students to understand the progress of their learning, what they have attained, and what is expected of them to improve their learning. Assessment for learning also provides teachers with evidence of student learning, enabling them to timely review the curriculum planning and teaching practice. It focuses on developing students' knowledge and understanding in an on-going and dynamic manner. Students use the feedback obtained from reflection and monitoring to make adaptation and adjustments to the learning objectives and strategies.

Assessment as Learning engages students in reflecting on and monitoring their progress of learning through establishing their roles and responsibilities in relation to their learning and assessment.

Assessment for learning encourages self-assessment and peer assessment as part of the regular classroom routine, while assessment as learning encourages peer assessment and self-reflection.

Self-assessment involves students in thinking about what and how they are learning based on an established set of criteria during the process of learning. This provides feedback to students to self-reflect and adjust their learning strategies.

Peer assessment involves students in evaluating the performance and the quality of their peers' work based on a set of predetermined criteria prepared by teachers. It can be conducted with individual students or in small groups. Feedback from peers benefits both the student receiving the feedback and the student providing it. If the feedback is given in a constructive way, it facilitates students to have dialogues with their peers about mutual learning goals and helps deepen both parties' understanding of these goals.

Self-assessment and peer assessment make unique contributions to the development of student learning by enabling them to monitor their own progress of learning and develop metacognitive skills through a more reflective approach to learning. At the same time, students can develop a greater sense of ownership, responsibility and confidence in the process of learning. Self-assessment and peer assessment, if appropriately used, can facilitate the development of students to become self-directed learners.

Provision of quality feedback is essential in formative assessment. To promote learning, teachers need to go beyond assessing their students and provide meaningful and helpful feedback in response to students' work. Without any constructive feedback, continuous assessment of students' work is not an effective assessment practice.

Through quality feedback, students learn how well they are achieving with regard to the expected learning outcomes, and what they need to do to improve their performance. Quality feedback should be precise and concrete advice for improvement that can be easily understood by students, help them close the gap between their performance and the expected learning outcomes, as well as modify their personal learning strategies.

5.2.2 Summative Assessment

Summative assessment can be viewed as assessment of learning. It provides information about what students have achieved at the end of a teaching unit or a school term/year. Common examples of summative assessment are tests and examinations in schools and public examinations, which involve measuring the standard or level a student has attained and reporting it in terms of marks or grades. Summative assessment provides performance data which can be used to compare different groups of students or different systems. However, summative assessment has its own limitations (e.g. in providing timely feedback to inform learning and teaching) and should not be used by teachers or schools as the only assessment strategy.

5.2.3 Formative Use of Summative Assessment

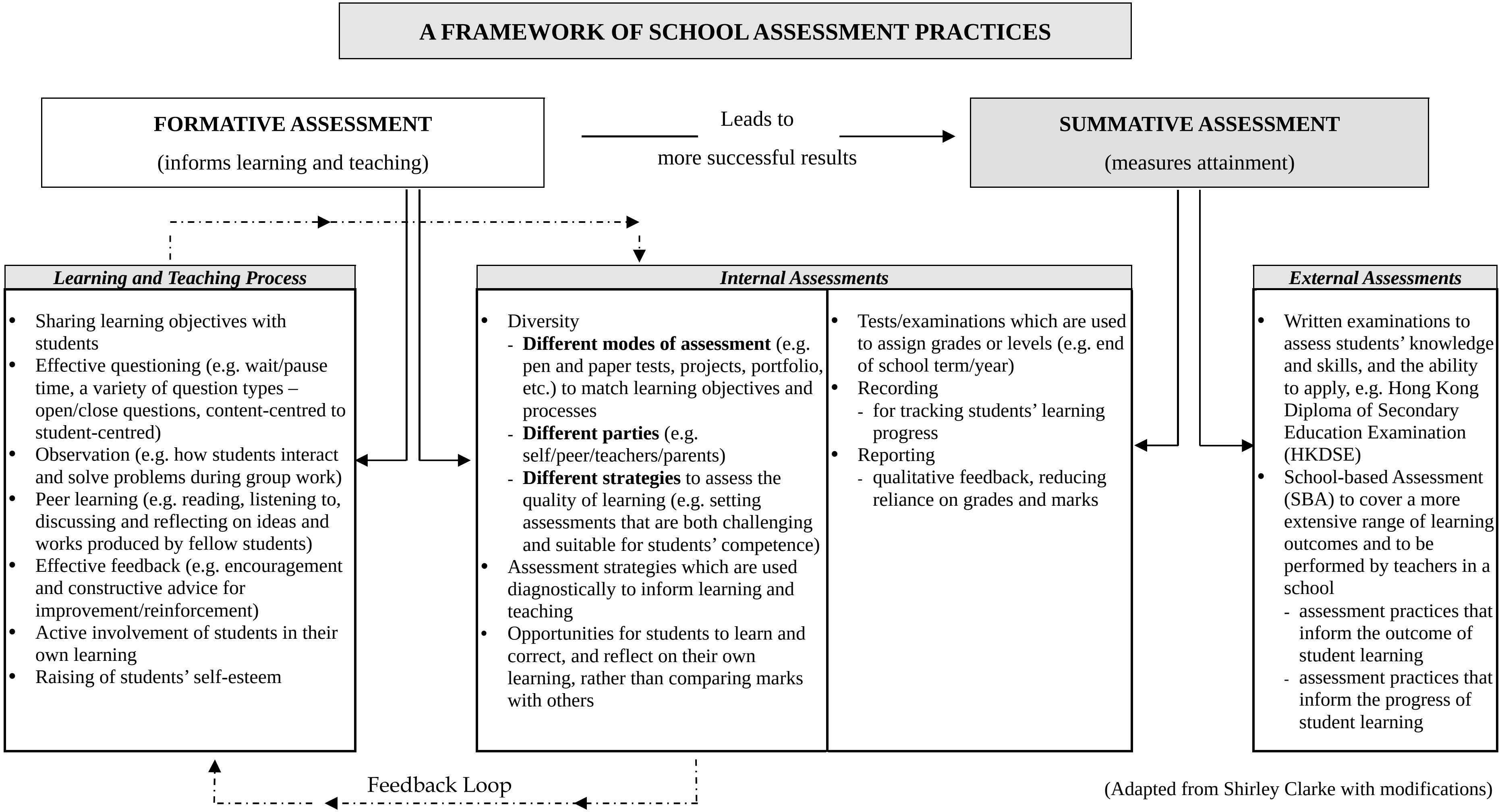
Assessment purposes are differentiated by how the evidence of student learning is used, e.g. to support feedback for enhancing learning, to make a summary judgement on students' attainments. Indeed, evidence collected for summative use can also be used formatively. Students' performance in tests can be used diagnostically by teachers to gauge students' learning needs and revise the classroom instructions. For instance, students are usually assessed by tests after completing each learning unit. Not only can these assessment results indicate how much learning has been achieved, they can also be treated as a portfolio of assessment evidence in the course of learning when constructive feedback from teachers is incorporated. In so doing, continuous assessment can serve the dual purpose of both formative and summative assessments.

5.3 Modes of Assessment and Reporting

5.3.1 Basic Principles in Designing Science Internal Assessment

The ultimate goal of assessment is to improve student learning. As such, internal assessments should be in line with the curriculum aims, objectives and intended learning outcomes so that a rich source of assessment information can facilitate the provision of feedback on students' ongoing learning and development.

In designing Science assessment tasks, teachers should take into account students' prior learning and their current progress in learning. Due consideration should also be given to learner diversity, especially gifted students who usually need alternate modes of assessment to enable them to fully demonstrate their thinking and learning. A variety of assessment modes and strategies are needed to truly reflect students' performance or progress in learning science. For instance, written examinations may not be able to fully reflect students' performance in relation to the science process skills in practical work and scientific investigation. An appropriate assessment mode should therefore be adopted to cater for the different learning objectives being assessed. A framework for organising school assessment is provided in Figure 5.1. The figure illustrates the interrelationship of formative and summative assessment, and the connection among learning and teaching, internal assessment and public assessment. Schools can refer to this figure in developing their assessment plans for the Science curriculum.



(Adapted from Shirley Clarke with modifications)

Figure 5.1 A Framework of School Assessment Practices

5.3.2 Modes of Assessment

Science teachers are encouraged to use the following modes of assessment flexibly in drawing up their assessment plans. Depending upon the scenarios of application, these assessment modes could be used for formative or summative assessment, or a combination of the two.

a) Pen and Paper Test

Pen and paper tests have been widely employed as the major mode of assessment in schools. However, the prolonged reliance on this mode has a narrowing effect on both learning and teaching. Teachers should avoid setting only recall tests which assess students' retrieval of information from memory and should try to construct test items that assess students' understanding of concepts, problem solving abilities and higher order thinking skills. Incorporation of open-ended questions in tests and examinations could help evaluate students' creativity and critical thinking skills. Teachers should analyse students' performance in tests and examinations, and use the information for future planning as well as helping students identify their strengths and weaknesses.

b) Written Assignment

Written assignments provide information about students' progress, efforts, achievements, strengths and weaknesses. Teachers are encouraged to use it as a tool for formative assessment. The scores or grades for written assignments can be part of the record of students' progress in learning science. They provide information for teachers to set further learning targets and objectives for students and adjust their teaching strategies. Valuable feedback, particularly comments on students' written work with concrete suggestions for improvement, should be provided to help students understand their strengths and weaknesses.

c) Oral Questioning

Through oral questioning, teachers gain specific information on how students think in certain situations. Students' responses often provide clues to their strengths, weaknesses, level of understanding, misunderstandings, interests, attitudes and abilities. Teachers are encouraged to use a wider range of questions involving fact finding, problem posing, sense of reason and seeking for truth to promote higher order thinking. Problems based on information that is unfamiliar to students could also be set. A balance between open-ended and closed-ended questions should be maintained. Teachers should allow time for students to respond and listen carefully to the responses with an open mind. Quality feedback and follow-up questions should be used to help students reflect on their learning and to offer them challenges.

d) Observation

While students are working in groups or individually, teachers can observe and note different aspects of their learning. In learning activities, teachers should observe the approaches students take to solve problems and whether they display attitudes such as perseverance, independence, cooperation, and willingness to address difficulties. In practical sessions, teachers can find out the choices students have made with regard to the equipment they use, the safety measures they adopt, the activities they prefer, and whom they work and interact with. Teachers should keep brief records of their observation and use such information for making further judgements about student learning.

e) e-Assessment

e-Assessment provides immediate feedback to students and can be used for both formative and summative assessments. Through e-assessment, students may have a more active involvement in monitoring their own learning. Teachers may also track individual students' performance while the assessment activity is still in progress, identify their strengths and weaknesses, and thereby provide timely support and intervention to enhance student learning.

To facilitate the implementation of assessment for learning and assessment as learning, teachers may combine e-assessment with relevant strategies and activities for learning and teaching. For instance, a teacher may assign students to complete some assessment items uploaded to an online platform after finishing a unit for checking their understanding. By analysing students' performance, the teacher can review students' understanding and misconceptions on the related topic. Further discussion and clarification can be conducted with students immediately online or in the next lesson in class. In addition, e-assessment facilitates students' self-directed learning. By using online assessment with instant feedback, students can monitor and evaluate their own learning progress and achievements, and take action to timely adjust their learning strategies or seek for help.

f) Practical Assessment

To have a comprehensive assessment of students' attitudes and practical skills, Science teachers should carry out practical assessments over a period of time based on students' performance in practical work during class time, scientific investigations as well as in practical tests. Assessment of daily practical work through observation is generally carried out in an authentic environment where learning and assessments are integrated, and feedback can be given to students immediately.

Scientific investigations provide opportunities for students to demonstrate their resourcefulness, ingenuity, originality, creativity, critical thinking and perseverance. Teachers can use appropriate criteria to assess students' scientific knowledge, application of scientific method, problem solving and communication skills, ability to handle, analyse and present data, safety awareness, and interest and enthusiasm in the scientific investigation. Students' written laboratory or investigation reports can serve as an effective means of assessing students' performance in science activities and provide a more complete picture about student learning.

Practical tests can be organised to focus on assessing the process and product of learning. Students can be assessed on whether they can follow and carry out instructions accurately, use an apparatus effectively and safely, observe or measure accurately and systematically, present results in a precise and logical form and draw conclusions from the results of experiments. Students should be told in advance how their performance would be assessed, e.g. observing them conducting the practical test and questioning them, marking the work submitted by them at the end of the practical test, or using both methods.

g) Project Work

Project work allows students not only to exercise their practical skills and apply what they have learned in science and other disciplines including mathematics and technology, but also to employ various skills and thinking processes such as identifying problems, formulating hypotheses, designing and implementing strategies, and evaluation. They should also be given opportunities to share with others what they have been involved in the process of carrying out the project, e.g. through project presentation. Teachers can make use of a combination of assessment strategies to collect evidence of student learning in the domains of knowledge and skills, and gauge their creativity, critical thinking skills, communication skills, collaboration skills and problem solving abilities. Teachers can also make use of appropriate criteria to assess students' values and attitudes demonstrated in the process of carrying out a project.

h) Portfolios

A portfolio is a purposeful collection of a student's work that demonstrates his/her knowledge and understanding, process skills, value and attitudes in a given area of study. It also provides a continuous record of the student's development in these three aspects. It allows teachers and parents to gain insights into the student's progress and achievements, and allows the student to have self-reflection and self-evaluation by revisiting his/her own portfolio.

The assessment strategies suggested above are by no means exhaustive. Teachers should explore other appropriate assessment strategies to meet the needs of their schools and students. Adopting a combination of assessment strategies enables Science teachers to build up a comprehensive picture of students' achievements.

5.3.3 Assessment for STEM-related Learning Activities

One of the objectives of STEM education is to strengthen students' ability to integrate and apply knowledge and skills from different STEM-related disciplines. Assessment tasks for STEM-related learning activities should therefore cover knowledge, skills and attitudes from the Science, Technology and Mathematics Education KLAs, as appropriate, to reflect the performance and capability of the students as independent and collaborative learners.

At the school level, formative assessment which serves the purposes of "assessment as learning" and/or "assessment for learning" should be adopted to collect evidence of student learning in the domains of knowledge and skill. On top of integration and application of knowledge and skills, problem solving and creativity should also be included, where appropriate, in the assessment tasks according to the nature and progress of the STEM-related learning activities. In the process of learning and teaching, various assessment strategies, such as oral questioning and class discussion, observation, self-assessment and peer assessment, and presentation of relevant designs/plans for the STEM projects, can be adopted. These assessment strategies allow teachers to collect evidence of students' learning, provide them with timely and constructive feedback, and guide them to monitor and reflect on their own learning. By the end of a series of STEM learning activities, summative assessment strategies such as assessing students' final products or written reports can be used to provide comprehensive information about the learning outcomes.

5.3.4 External Assessments

Upon completion of the six-year secondary education, students will take the Hong Kong Diploma of Secondary Education (HKDSE) Examination and are measured by levels of achievement. The public assessment of the senior secondary subjects of the Science Education KLA consists of a public examination component and a school-based assessment component.

The overall aim of the public examination is to assess students' ability to demonstrate their knowledge and skills in various parts of the subjects, and their application in different scenarios. A variety of items, including multiple-choice questions, short questions, structured questions and essays, are used to assess students' performance covering a broad range of knowledge and skills. Schools may refer to the live examination papers regarding the format of the examination papers and the standards at which the questions are pitched at. Details of the assessment design and framework are available at:
www.hkeaa.edu.hk/en/hkdse/assessment/assessment_framework/.

School-based assessment (SBA) is another component of the public assessment for all senior secondary subjects of the Science Education KLA. SBA refers to assessment administered in schools and marked by the students' own teachers. The rationale for implementing SBA in the science subjects is to enhance the validity of the assessment by including the assessment of students' practical skills and generic skills. Details of the SBA for all Science subjects are available at: www.hkeaa.edu.hk/en/sba/sub_info_sba/.

Chapter 6
Learning and Teaching Resources

Chapter 6 Learning and Teaching Resources

A good variety of resources should be used to enhance the effectiveness of the learning and teaching of science. Besides textbooks, resource materials that provide students with learning experiences beyond the school and give support to students in developing their scientific knowledge and skills are useful for extension of learning, addressing diverse learning needs and promotion of self-directed learning.

To optimise the use of resources for enhancing the effectiveness of science education in schools, appropriate planning and management of learning and teaching resources ought to be agenda items regularly reviewed at the subject, KLA and school levels with appropriate follow-up actions.

6.1 Curriculum Documents

To provide comprehensive support to the learning and teaching of science at different key stages, a set of curriculum documents are issued in addition to this Guide.

- *Basic Education Curriculum Guide – To Sustain, Deepen and Focus on Learning to Learn (Primary 1 – 6)* (2014)
- *General Studies for Primary Schools Curriculum Guide (Primary 1 - 6)* (2017)
- *Supplement to the Science Education Key Learning Area Curriculum Guide: Science (Secondary 1 - 3)* (2017)
- *Biology Curriculum and Assessment Guide (Secondary 4 - 6)* (2007) (with updates in November 2015)
- *Chemistry Curriculum and Assessment Guide (Secondary 4 - 6)* (2007) (with updates in November 2015)
- *Physics Curriculum and Assessment Guide (Secondary 4 - 6)* (2007) (with updates in November 2015)
- *Integrated Science Curriculum and Assessment Guide (Secondary 4 - 6)* (2007) (with updates in November 2015)
- *Combined Science Curriculum and Assessment Guide (Secondary 4 - 6)* (2007) (with updates in November 2015)

The latest versions of the above curriculum documents for the primary and secondary levels are available at the following websites:

Primary level
www.edb.gov.hk/en/curriculum-development/kla/general-studies-for-primary/index.html

Secondary level
www.edb.gov.hk/en/curriculum-development/kla/science-edu/index.html

6.2 Quality Learning and Teaching Resources

For effective learning and teaching of science, the availability of quality resources is as important as the curriculum design, pedagogy and assessment practice. Apart from textbooks, there are online learning and teaching resource materials as well as resources from science laboratories, school and public libraries, etc. which could benefit student learning. Quality learning and teaching resources could enhance the interest of students in their studies, broaden their perspective of science and technology, promote critical thinking and creativity, provide prompt support to those in need, and hence strengthen the effectiveness of learning and teaching science.

6.3 Textbooks

Quality Science textbooks can motivate students and enhance the effectiveness of learning and teaching. The EDB has developed a set of Guiding Principles for Quality Textbooks (www.edb.gov.hk/en/curriculum-development/resource-support/textbook-info/GuidingPrinciples/index.html) to provide criteria for schools and teachers in selecting quality textbooks for their students. Reference can also be made to the Recommended Textbook List (www.edb.gov.hk/rtl) and the Recommended e-Textbook List (www.edb.gov.hk/ertl) which provide lists of printed or electronic textbooks (e-textbooks) which have been reviewed by the EDB.

6.3.1 Choosing Textbooks

It is crucial to have quality textbooks selected or developed to facilitate learning and teaching. Quality textbooks, including printed and electronic textbooks, should be designed to support the local school curriculum and comprise suitable learning strategies for studying the subject. The amount and quality of the texts to be included therefore deserve attention. Other desirable features of a good textbook include interactivity, and appropriately designed examples and learning activities to enlighten and arouse the interest of students in the subject, and to actively engage them in the learning process.

Quality Science textbooks should, specifically:

- provide a clear purpose and direction for learning science;
- alert teachers of students' prior knowledge in science;
- provide accurate and up-to-date information on science ideas and applications;
- present scientific phenomena and theories in a systematic way;
- elaborate scientific phenomena, by means of appropriate examples, to help students understand the phenomena and apprehend relevant scientific theories and applications;
- guide students to inquire, interpret and reason scientifically according to observations, experimental results and other scientific evidence;
- provide opportunities for students to integrate and apply knowledge and skills, and, where appropriate, to make connections between subjects of science-related disciplines;
- include tasks for assessment of learning, assessment for learning and assessment as learning and offer prompt feedback to students and teachers;
- encourage and provide hints to students to further pursue topics of interest in science; and
- incorporate appropriate measures to embrace learner diversity.

When choosing textbooks for students, Science teachers need to exercise professional judgement and take into consideration the educational needs, the abilities of their students and the affordability of the parents. They can also assess if there is a genuine need to use supplementary materials such as workbooks, exercises, examination practice papers and/or other digital resources developed in line with a specific set of textbooks. The following is a list of teachers' major considerations when selecting printed textbooks or e-textbooks for Science subjects:

- the approach and coverage of the textbooks – whether they could facilitate the development of knowledge, skills, and values and attitudes as emphasised in the Science Education curriculum;
- the suitability and accuracy of the teaching content;
- the quality and level of difficulty of the language used;

- the appropriateness of the learning and teaching activities;
- the layout, examples and illustrations − whether they are appropriate and helpful to support learning; and
- the design of the practical work including the instructions for students and safety precautions.

For e-textbooks, additional considerations include:

- the pedagogical use of e-features; and
- the accessibility and operational design.

6.3.2 Using Textbooks

Textbooks are written to facilitate both learning and teaching. With good knowledge of the students, teachers need to use Science textbooks flexibly according to the needs, abilities and interests of their students. Sufficient guidance ought to be provided to help students grasp the major content in the textbooks and make good use of the textbooks for self-directed learning before and after lessons. To match the school Science curriculum and to cater for differences in the learning progress, the content of a textbook can be adapted or re-sequenced whenever appropriate. In summary, attention needs to be paid to the following when using Science textbooks:

- keeping the learning targets and objectives of relevant key stages in mind and identifying the focus of each key stage;
- matching the content with the school Science curriculum and making sure that there is a balanced coverage of the learning targets and objectives;
- taking note to embrace learner diversity, e.g. adopting the extension questions/activities, if available, for the more able students, and omitting the more difficult parts for the less able students;
- adapting the content or the activities, where appropriate, to promote critical thinking, problem solving and creativity among students;
- attempting those learning/teaching activities which are essential to achieving the learning targets; and
- collecting feedback on learning by using activities that can facilitate assessment of learning, assessment for learning and/or assessment as learning.

6.4 Other Learning and Teaching Resources

Although textbooks can support student learning, they are not the only kind of learning and teaching resources to support science education. Schools are recommended to make good use of existing resources, such as equipment in science laboratories and other special rooms, IT facilities, audio and visual aids, library books, learning and teaching resources packages, for supporting the implementation of the Science Education KLA curriculum and for promoting STEM education. Some schools have set up their own eco-gardens, solar panels, weather monitoring systems, star glazing platforms, etc. which are useful resources to enrich students' learning experiences in science and technology. The school library serves as a resource bank which provides access to timely information in various formats (e.g. reference books, journals and multimedia resources/equipment), to support the learning and teaching of science and STEM-related disciplines both inside and outside the classrooms.

6.4.1 EDB Resources in Support of the Science Curriculum

Over the years, many printed, digital and online resource materials have been developed by the EDB to support the learning and teaching of science in schools. The major items are listed in Appendix A3. Students and teachers are welcome to use these resources where appropriate.

The "EDB One-stop Portal for Learning and Teaching Resources" (www.hkedcity.net/edbosp) has also been set up at the Hong Kong Education City for students and teachers to get easy access to the large quantity of web-based resources developed to support the learning and teaching of science and STEM-related disciplines.

Other useful resource materials for teachers include those developed through a number of school-based projects sponsored by the Quality Education Fund (QEF). Relevant information of the resource materials developed is available at the Quality Education Fund Cyber Resource Centre (qcrc.qef.org.hk/).

6.4.2 Community Resources

The implementation of the Science Education curriculum and STEM education are not confined to the school campus. Resources available from other government departments, non-governmental organisations, tertiary institutions, professional bodies, etc. could be utilised to facilitate life-wide learning of science and technology, and enrich the learning experiences of students. Community resources useful for science education and STEM education include many public facilities or sites (e.g. The Hong Kong Science Museum, Health InfoWorld, science and technology centres, nature reserves) which are accessible to everyone and provide valuable opportunities for students to investigate and explore, to create and innovate, and to interact and collaborate. Besides, many science exhibitions and competitions drawing on various themes are organised by different organisations every year and welcome students' participation. Through visits, field trips, surveys, workshops, etc., students would not only develop their interest in science, but also build up their competence to apply knowledge and skills of different subject disciplines to solve authentic problems. An updated list of useful community resources for science education is provided in Appendix A4.

6.4.3 Using Other Learning and Teaching Resources

Learning and teaching resources other than textbooks may include reference books, models, computer simulation programmes, e-learning materials and community resources. While some of these may be used for class teaching, many are developed or chosen to facilitate self-directed learning.

The abundant online resources, including video clips, interactive programmes, social community platforms, etc. foster e-learning among students and provide learning opportunities to keep students abreast of the latest scientific and technological developments in the world. Students could learn new knowledge and skills at their own pace and seek advice from adults and peers when in need. Appropriate use of portable electronic devices, including data-loggers, tablet computers and smartphones, can enrich the learning experiences in science. Some schools have started exploring the use of 3D printing technology for the production of models to facilitate learning and teaching, or making special apparatus or parts to facilitate scientific investigation or STEM-related projects.

The principle that can be adopted when choosing resource materials of different contents, formats, designs or versions (whether online or printed) is “fitness for purpose”. In other words, learning and teaching resources developed/chosen to support science education need to meet the following criteria, to support or extend student learning where appropriate:

- align with the objectives of the science learning;
- arouse students’ interest in learning science;
- meet the learning needs and abilities of students;
- encourage exploration, and integration and application of knowledge and skills;
- provide prompt feedback for self- or peer assessment; and
- promote self-directed learning.

6.5 Resource Management in Schools

Availability and effective use of quality learning and teaching resources are both essential for successful implementation of the Science Education curriculum. Schools need to consider the whole-school curriculum planning, and prioritise and allocate appropriate resources to facilitate the implementation of the school Science curriculum. The Science Education KLA co-ordinators, Primary School Curriculum Leaders, panel chairpersons of General Studies in primary schools and panel chairpersons of different Science curricula in secondary schools should plan with the teachers concerned collaboratively to ensure transparency in the process of allocating resources necessary for accomplishing various school initiatives related to science education. Besides planning, they also need to closely monitor the utilisation of the resources on promoting science education.

In secondary schools, the laboratory technicians can assist teachers in the development and implementation of the Science curriculum through planning, trying out and conducting science experiments, providing relevant demonstrations, as well as assessing students’ performance in science-related practical activities. For experiments, demonstrations and scientific investigations to be carried out smoothly in the laboratories, the laboratory technicians need to properly manage the equipment and facilities, and safeguard laboratory safety as routine duties. They need to timely procure necessary equipment and consumables, properly store and retrieve equipment and consumables for use by teachers and students when necessary, regularly check and stock take equipment and consumables, conduct tests and properly maintain the equipment to ensure that they are in sound conditions, and also keep a clear record of the inventory and other relevant documents, e.g. regular safety inspection/test records, laboratory accident records.

The effectiveness of resources deployed to facilitate learning and teaching needs to be regularly reviewed. With consensus sought among stakeholders, timely adjustment and flexible re-allocation of resources is usually needed to attain the set objectives.

6.6 Partnership with Key Players in the Community

All along, the EDB has been engaging different stakeholders in the promotion of student learning in science/STEM-related areas, and there is a need to further strengthen the partnerships with them. The communication with the school sector as well as the local curriculum advisory committees will be further enhanced for facilitating student learning in science or science-related areas.

Through liaison with academics and practitioners who are specialised in various fields of science, technology, engineering and mathematics, the EDB will explore the feasibility of collaborating with tertiary institutions and specialists in organising student learning activities and teacher professional development programmes.

The EDB will continue to strengthen the partnerships with professional bodies, government departments (e.g. Leisure and Cultural Services Department, Agriculture, Fisheries & Conservation Department) and also non-governmental organisations (e.g. Hong Kong Science Park) and play a pivotal role in fostering synergy within the community for promoting science education and STEM education.

6.7 Professional Development of School Leaders and Teachers

While schools are generally aware of the capacity building needs of their teachers and arrange staff development programmes regularly to address their needs, the EDB will continue to support schools and teachers by organising professional development programmes to strengthen the professional capacity of teachers and school leaders. Relevant PDPs are also provided for laboratory technicians.

To enhance the professional capacity of curriculum leaders and teachers in implementing science education and STEM education holistically and effectively at the school level, the EDB will continue in strengthening the following:

- Organising symposia for curriculum leaders — To serve as a hub to engage stakeholders in the promotion of STEM education among local schools
- Organising seminars and workshops for middle managers and teachers — To introduce the most up-to-date development in STEM-related fields and appropriate strategies to enhance the effectiveness of learning science and students' ability to integrate and apply knowledge and skills within and across KLAs
- Setting up communities of practice among Science teachers — To make use of different platforms (e.g. Professional Development Schools Scheme (PDS) of Education Development Fund (EDF)) to facilitate sharing of professional knowledge and experience in promoting science education and STEM education within and across schools
- Arranging meetings with academics in the territory, from the Mainland and overseas — To enrich teachers' exposure to the cutting edge of developments in science and technology fields

Booklets on the professional development programmes for primary and secondary school heads and teachers are produced annually and uploaded to the EDB website (www.edb.gov.hk/en/curriculum-development/list-page.html) to assist schools in planning their PDPs before the commencement of each school year. Details of PDPs relevant to science and STEM-related topics available for participation by school heads, teachers and laboratory technicians are uploaded in phase to the Training Calendar System of the EDB (tcs.edb.gov.hk).

6.8 Curriculum Development Projects

The purpose of launching curriculum development projects in the Science Education KLA is to:

- develop a critical mass of curriculum change agents, through networking activities, to enhance teachers' professional capacity to cope with the changes;
- generate useful experiences and develop exemplary learning and teaching materials for the reference of schools and teachers; and
- act as an impetus to school curriculum development.

A list of curriculum development projects in recent years is tabulated in Table 8. While good experiences have been acquired through curriculum development projects on various themes in the past, schools are encouraged to further explore, try out and adopt the recommended strategies that could help students achieve the learning targets of the Science Education curriculum. The EDB will continue to conduct curriculum development projects related to the primary General Studies and secondary Science curricula for enhancement of student learning.

Table 8 Curriculum Development Projects on Science Education

Curriculum Development Projects on Science Education by the EDB		
Theme	**Level**	**Aim/Content**
Learning and Teaching Resource CD for Primary General Studies (2014-17)	Primary	The project aimed to support schools in the implementation of Science and Technology education in the General Studies curriculum. Through various learning activities, students were able to explore and learn in an authentic environment, so that they could construct knowledge and skills of science and technology, as well as arousing their curiosity towards the natural and technological world. The resource package also includes learning activities related to STEM education, which aims at strengthening the ability of students in the integration and application of knowledge and skills of different STEM-related disciplines. Deliverable CD-ROM (Bilingual version) Chinese web version: www.edb.gov.hk/tc/curriculum-development/kla/general-studies-for-primary/learning-and-teaching_resource_cd_st/index.html English web version: www.edb.gov.hk/en/curriculum-development/kla/general-studies-for-primary/learning-and-teaching_resource_cd_st/index.html

Curriculum Development Projects on Science Education by the EDB		
Theme	**Level**	**Aim/Content**
Promoting Talking and Writing in Science at Junior Secondary Level Using English as the Medium of Instruction (2013-16)	Secondary	The project aimed to strengthen teachers' professional capability on the pedagogical knowledge and strategies on teaching science using English as the medium of instruction, as well as promoting talking and writing in the language of science through collaboration between Science teachers and English teachers. Good practices on promoting Language across the Curriculum in enhancing the effectiveness of student learning in science were consolidated for sharing. <u>Deliverable</u> Resource package (English version only)
Promoting Assessment for Learning in Junior Secondary Science through Identifying Students' Learning Difficulties from Secondary Analysis of TIMSS and Refining Classroom Learning &Teaching Practices (2012-15)	Secondary	The project aimed to enrich teachers' understanding of quality assessment for effective learning and teaching in science and to highlight to teachers students' common misconceptions and learning difficulties in grasping science ideas. Through analysing students' performance in TIMSS and relevant tryouts in class, relevant strategies and pedagogies to identify and tackle students' learning difficulties were consolidated. <u>Deliverable</u> Resource package (English version only)
Interfacing of Junior Secondary Science Curriculum with Senior Secondary Science Curriculum (2005-07)	Secondary	This seed project aimed to explore the strategies for planning the Science (S1 - 3) curriculum that could help to pave the way for students to study science at the senior secondary level. The key focus of the project was to consolidate learning and teaching practices that could enhance the knowledge and skills of junior secondary students and prepare them for the study of science at the senior secondary level. <u>Deliverable</u> CD-ROM (English version only)

Curriculum Development Projects on Science Education by the EDB		
Theme	**Level**	**Aim/Content**
Writing and Application of Physics Specific Genres (2013-14)	Secondary	The aim of the project was to enhance the reading and writing proficiency of students in learning Physics at the senior secondary level. Frontline Physics teachers and tertiary educators participated in and contributed to the project. Professional dialogues among experienced Physics teachers, tryout of innovations in class, assessment of students' performance, etc. were also carried out in the project. The experiences acquired in the project were collated and consolidated as online resources for teachers' reference to commonly-used Physics genres. <u>Deliverable</u> Chinese web version: edb.hkedcity.net/phygenres/zh/index.htm English web version: edb.hkedcity.net/phygenres/en/index.htm
Enhancing Conceptual Understanding in Chemistry with Quality Assessment Items and Classroom Response System (2013-14)	Secondary	The project aimed to enhance students' understanding of Chemistry by using quality assessment items and IT. A Classroom Response System (CRS) and quality assessment items were used to demonstrate how teachers might improve student engagement, teacher-student interaction, and learning and teaching in Chemistry lessons. Annotated assessment items in various topics in the Chemistry curriculum were developed and tried out with the use of the CRS in schools. <u>Deliverable</u> Assessment items

Curriculum Development Projects on Science Education by the EDB		
Theme	**Level**	**Aim/Content**
Supporting the implementation of e-learning and e-assessment in Chemistry (2015-16)	Secondary	The project aimed to provide support for chemistry teachers to use e-learning and e-assessment strategies in chemistry lessons through on-site school-based support and also Communities of Practice meetings. Appropriate resource materials for the implementation of e-learning and e-assessment in schools were developed in the project. The related experience was consolidated and shared with teachers.

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Examples

Examples

Example 1

Developing Collaborative Problem Solving Skills in Project Learning (for the Primary Level)

Level: Primary 1 - 3 **Curriculum:** Primary General Studies

Emphasis: Project learning, collaborative problem solving skills

Aim: To develop collaborative problem solving skills of lower primary students in project learning

Project title： How can we reduce waste in our school?

Learning elements：the importance of caring the environment, ways of reducing waste in daily life (e.g. Reduce, Reuse, Recycle and Replace)

Teaching Process	Activities	Related generic skills, values and attitudes
Pre-lesson preparation	Each group of students reads and searches for information of “4Rs of Environmental Protection” and finds out the waste in their school.	Self-learning skills
Lesson activity	• Students share their preparation work and talk about what are the sources of waste in their school and why they should reduce waste. • The leader of each group leads the discussion and gives suggestions on reducing the waste in the school, such as by using re-usable cutlery, recycling plastic bottles into usable items, etc. • Students share their views with other groups and make a plan on “Reducing waste in our school” collaboratively under the teacher’s guidance.	Communication skills, Collaboration skills, Problem solving skills Respecting others’ views during discussion
Extended activity	To implement the plan in school, such as converting a used plastic bottle into a flowerpot.	Creativity, Responsibility

Example 2

Developing Science Process Skills in Scientific Investigation
(for the Primary Level)

Level: Primary 4 - 6 **Curriculum:** Primary General Studies

Emphasis: Scientific Investigation, science process skills

Aim: To develop the science process skills of upper primary students in scientific investigation

Topic: Investigation on Electrical Circuits		
Learning element: To recognise some patterns and phenomena which are related to electricity		
Process of scientific investigation	**Activities**	**Relevant science process skills**
Proposing questions	In a closed circuit, if the types and the number of battery remain unchanged in 3 different closed circuits, what is the relationship between the number of light bulbs connected in a line (in series) and their brightness?	
Predicting results	Under the above situation (with the number of battery remains unchanged), students may predict the change of brightness against the light bulbs. For example, students may predict that with more light bulbs connected, the light bulbs will be brighter. Teachers should provide opportunities for students to think and explore the answers themselves instead of giving them the correct answers directly.	Predicting, Communicating
Conducting investigations	Students work in groups to connect 3 different circuits consisting of one, two and three light bulbs “in a line” respectively (Figure a). In order to help students identify the variables in the fair test, teacher guides students to think about questions such as: • In the experiment, what are the differences between the three closed circuits? • What do we need to measure? • Which factors remain unchanged?	Observing and recording Identifying variables

	As guidance to students in exploring the phenomenon, the teacher asks the students to observe, and compare the brightness of light bulbs in the three different circuits. Students in each group then discuss and analyse the results of the experiments.	Analysing/inferring
Interpretation of results	Under the teacher's guidance, students are requested to interpret the results and draw a conclusion from the investigation. (Conclusion of the investigation: in the closed circuit as shown, given that the types and the number of batteries remain unchanged, if the number of light bulbs increases, the brightness of the light bulbs decreases.)	Analysing/inferring, communicating

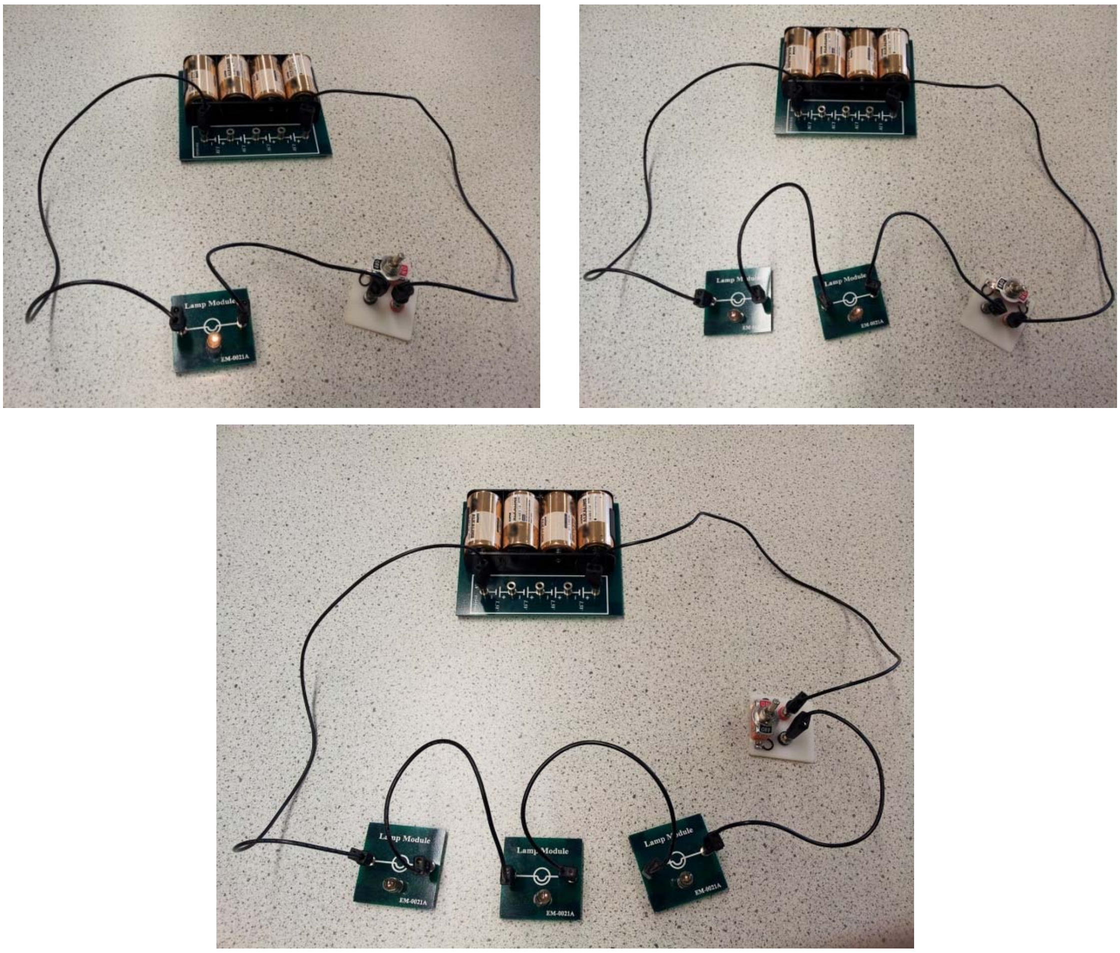


Figure a

Example 3

Promoting STEM Education through Project Learning (for the Primary Level)

Level: Primary 4 - 6

Curriculum: Primary General Studies, Mathematics

Emphasis: Project learning, STEM education

Aims:

1. To solve an authentic problem by integrating STEM-related learning elements of General Studies and Mathematics.
2. To develop collaborative problem solving skills, science process skills and mathematic skills, as well as creativity.

Description:

This activity covers the learning elements of both General Studies and Mathematics. It provides students with opportunities to integrate and apply their knowledge and skills for solving authentic problems. Through this project learning, students can demonstrate their creativity and unleash their potentials in innovation.

Task: Design and make a water-saving device for our school?

STEM-related learning elements:

<u>General Studies</u>

- scientific hands-on and minds-on investigation activities
- the use and characteristics of some common materials
- concepts and application of the design cycle
- effective use of resources

<u>Mathematics</u>

- find the average of a group of data
- develop an understanding of division of decimals through daily life examples
- construct compound bar charts
- estimate the average from bar charts

Learning activities:

(1) Preparation Stage – Idea Initiation

- Students found that a lot of water is used for cleaning the utensils after the lunch time in the school. Therefore, they try to find a way to save water.
- A task is therefore assigned for the students : design and make a water-saving device for our school

(2) Implementation Stage – Inquiry Process

- After observing, discussing and collecting information, each group of students proposes a solution for saving water (e.g. reduce water consumption by fitting a shower head on the water tap).
- Design and make the water-saving device (e.g. use a recyclable plastic bottle to make a shower head as illustrated in Figure b).
- Design a fair test to test the effectiveness of the water-saving device (e.g. select testing methods and identify the variables in the fair test).
- Record and analyse result.
- Improve the design of the device and conduct tests to observe the effect on water saving (e.g. change the water pressure of the shower head by putting in various materials, such as rags and sponge).

(3) Concluding Stage – Knowledge Building

- Information consolidation (e.g. students conclude and determine the type of shower head design that is most effective in saving water).
- Reflection and evaluation (e.g. identify the factors which may produce errors in the testing process).

Figure b

Example 4

Holistic Curriculum Planning of STEM Education in Secondary School

Level: Secondary 1 - 6 **Curriculum:** Cross-KLAs

Emphasis: Planning-Implementation-Evaluation, cross-KLA collaboration

Aims: To enhance students' interest in science and unleash their potential in STEM-related areas through effective planning of learning activities at different levels

Description:

<u>Background</u>

The management of a secondary school with student intake of average ability wants to enhance students' interest and confidence in learning science and other STEM-related subjects, and to more fully develop the potential of the more able students. They have decided to take actions at the planning level and line up different KLAs in planning and organising learning activities that can help promote STEM education in the school.

<u>School Planning</u>

With a participatory approach long adopted for management in the school, consensus is first obtained among teachers in staff meeting on the broad development direction in the next school development cycle before "Promotion of STEM education" is decided as an action to address one of the major concerns set for the next school development cycle, viz. "Enhancing the interest and effectiveness of students of different abilities in learning".

Teachers of the Science Education (SE), Technology Education (TE) and Mathematics Education (ME) KLAs are the key players in promotion of STEM education. To plan and co-ordinate the STEM-related functions at the school level, a working group was formed to work out a detailed plan that prioritises the many STEM-related activities for implementation in steps during the three-year school development cycle. For each event, prudent consideration is made on the resources, including financial and human, and other supports that are essential for smooth implementation of the activities.

The STEM-related events/activities proposed in the school development plan in the initial stage are based on the past experiences of the school, which include:

- An annual STEM Day/Week for which relevant KLAs will collaborate and organise exhibitions, quizzes, workshops, talks, etc. to arouse students' interest in STEM-related fields;

- The existing interest groups such as the Science Club, the Computer Club and the Mathematics Club are combined to form a STEM Club;
- Teachers of STEM-related KLAs are requested to collaborate and guide students on organisation of activities with more emphasis on cross-disciplinary knowledge and skills;
- STEM-related projects are planned for students regularly and each student is required to complete, at least, one STEM-related project during its study in the junior secondary level;
- More opportunities are arranged for students to participate in STEM-related competitions both within and outside the school. The winners within the school will be nominated to participate in relevant national and international competitions; and
- A small STEM corner is set up to showcase the students' inventions, relevant prizes won, news and photos of recent STEM events by the school, interesting science toys, news clips about recent advancement of science and technology in the world, etc. This STEM corner is open to all students during normal school hours.

To facilitate students' acquisition of knowledge and skills, some topics in the subjects of the SE, TE and ME KLAs have been re-sequenced or furnished with learning elements from other KLAs. At the same time, consideration is also made on embracing learner diversity with actions proposed at both the school level and KLA level to groom the more able students and provide learning support to the less able/less motivated students.

The school believes that teachers' competence and readiness are essential for successive implementation of STEM education. Therefore, based on the training needs of teachers, a professional development (PD) plan is formulated for capacity building of teachers to facilitate the promotion of STEM education. The training proposed includes cross-KLA programmes and KLA-based programmes offered by the EDB and other organisations. There is also in-house training for experience sharing and knowledge transfer among teachers within the school. The principal, vice-principal, KLA co-ordinators, panel heads and subject teachers attend the programmes whichever appropriate.

Resources are necessary for the implementation of STEM education in school. Besides deploying existing resources to facilitate the implementation of the STEM-related learning activities, the school management wants to make use of community resources. A list of resources/activities available from Hong Kong Science Museum, the Hong Kong Space Museum, and the Science Park, etc. is drawn up for teachers' reference when planning learning activities for students. Tertiary institutions, professional organisations and community stakeholders are also engaged to provide support to the school on projects and activities conducive to professional development of teachers and broadening students' learning experiences. Opportunities were also planned to share with parents about the school's effort to promote STEM education and to gain their support.

Implementation, Monitoring and Evaluation

A reporting system is in place to keep the school management timely informed about the progress of different tasks. While the co-ordinators of individual KLA and panel heads of different subjects are required to monitor the events/activities under their purview, the principal/vice-principal oversees the overall development of STEM education in the school and closely monitors/co-ordinates those events that involve cross-KLA collaboration.

A schematic diagram that illustrates the major steps of holistic curriculum planning of STEM education in a secondary school is shown in Figure c.

Holistic Curriculum Planning of STEM Education in a Secondary School

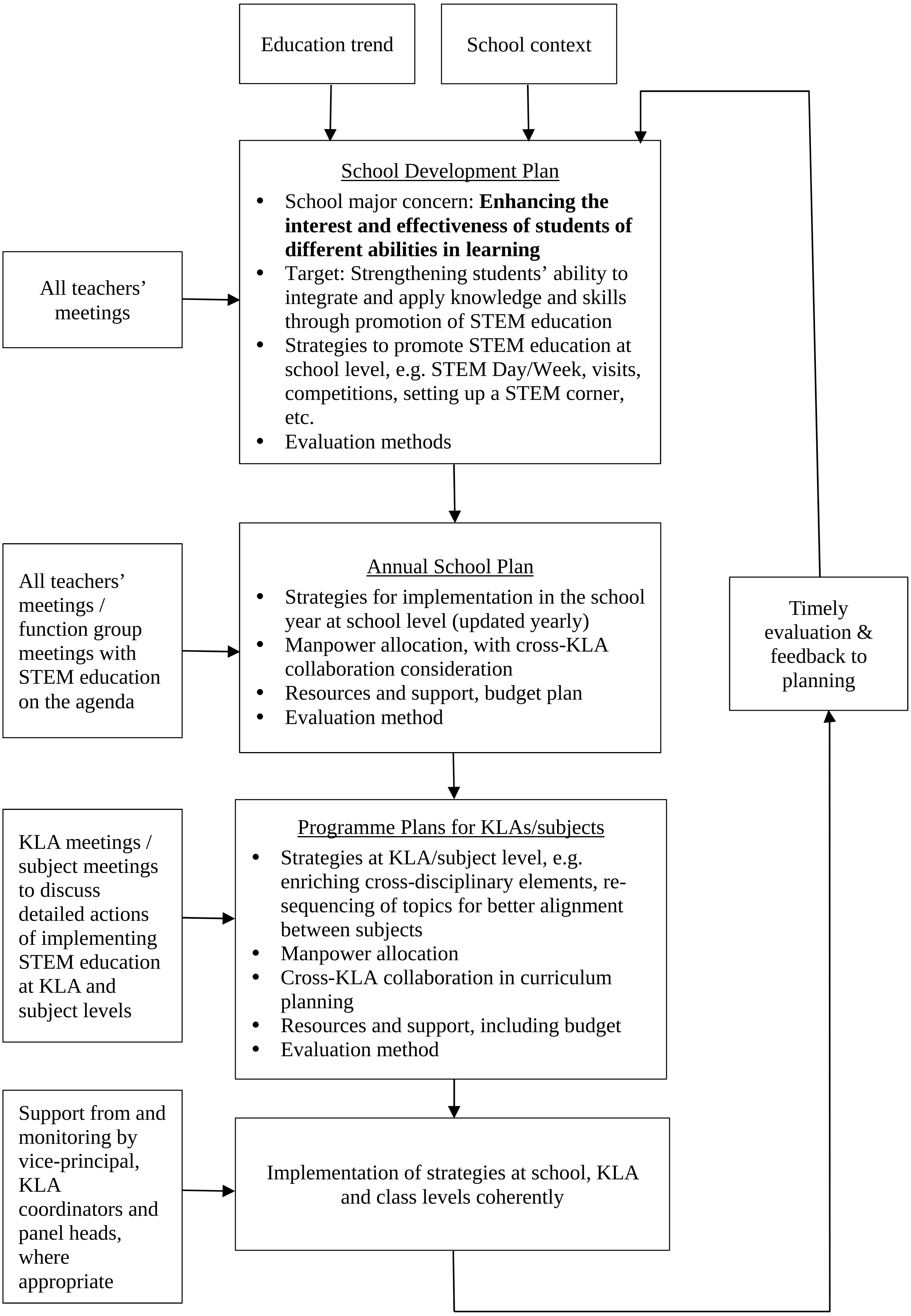


Figure c

Example 5

Strengthening Students' Science Process Skills

Level: Secondary 1 - 3 **Curriculum:** Science Education KLA

Emphasis: Scientific literacy, scientific investigation

Aims: To strengthen the science process skills of students at the junior secondary level

Description:
A solid foundation in science process skills of students at the junior secondary level not only enables students to solve problems in a logical way and enhances the scientific literacy, but also facilitates their learning of different senior secondary science elective subjects, and ensures a smooth interface in science learning between the junior secondary and senior secondary levels.

(A) Developing science process skills of students through scientific investigations

Strategies/Procedure:

- Science process skills can be developed in different ways, such as a project on scientific investigation for students. As an example, a project on investigating the factors affecting the falling time of a parachute can be used to develop the science process skills of students. Students are required to submit a group project proposal including the aim of the project, the factors to be investigated, the proposed experimental method, apparatus needed and a table showing all the independent and dependent variables.
- With teacher's comments and suggestions, students will further revise their proposal. After teacher's approval, students can conduct the investigation in school, record and analyse the data, draw conclusions with discussion on possible errors in the results and conduct a self-reflection.
- The project may be conducted in groups of three to four students. Each group needs to submit a report and will be given 10 minutes to present their investigation and results in class. Other students are encouraged to challenge the design and performance of their classmates' investigations, including the procedures, the findings and the conclusions etc.
- Finally, students are required to make a parachute according to their investigation findings and use the parachute to join an interclass competition as an extended learning activity.

(B) Strengthening science process skills of students through practical assessment

Conducting practical work provides opportunities for students to develop science process skills and problem-solving skills. Proper mastery of practical skills enhances safe and efficient exploration of phenomena around us. Hence, practical assessments provide information about students' competency in science process skills (e.g. handling apparatus, analysing data and drawing conclusions), as well as their understanding of the underlying scientific principles.

Strategies/Procedure:

1. During practical lessons, teachers may assess students' performance whenever they are doing experiments, e.g. assessing their attitude, safety awareness, handling of apparatus properly and the accuracy of the measurement.
2. In practical tests or examinations, practical assessments may conducted for different purposes:
   - Assessing skills related to conducting practical and observing, e.g. lighting a Bunsen burner, mixing solution, measuring temperature, observing and recording the result appropriately.
   - Assessing skills related to conducting practical and inferring, e.g. connecting circuits according to circuit diagram and finding out the relationship between current and voltage.
   - Assessing skills related to designing investigations and communicating, e.g. students are given a problem and asked to design an investigation to solve the problem. Students are required to perform experiments and write a report.

The practical assessment can be arranged in science lessons or during examination periods, with the help of science teachers, laboratory technicians or senior form science students if necessary.

Example 6

Developing Students' Ability to Integrate and Apply Knowledge and Skills of Different KLAs through Project Learning

Level: Secondary 1 - 3 **Curriculum:** Cross-KLAs

Emphasis: Project learning, integration and application of knowledge and skills

Aims:
- To raise students' awareness of healthy eating
- To develop students' ability to integrate and apply knowledge and skills across the Science, Technology and Mathematics Education KLAs
- To develop students' creativity, collaboration skills, problem solving skills and enhance their information literacy

KLA	Learning Elements
Science Education	• Common food substance • Function of food substance • Food pyramids • Balanced diet • Healthy lifestyles
Technology Education	• Dietary goals and eating habits • Principles and skills in food preparation • Use of computer networks
Mathematics Education	• Computing and interpreting data • Diagram and graphs

Background:
- In a secondary school, most of the S1 - 3 students order lunch boxes from a supplier chosen by the school through a quotation exercise. Both students and the school are concerned about the quality of lunch boxes from the supplier. On one hand, students are concerned about the taste, quality and quantity of the food. On the other hand, the school is more concerned about the nutritional values of the food which is so important to the health of their teenage students.
- The Junior Form (S1 - 3) teachers work collaboratively and ask students to conduct a group project on designing a diet menu for a healthy lunch box in order to help students understand what kind of healthy and quality food they should have for lunch at school.
- The teacher adopts a cross-disciplinary approach and the learning elements from the Science, Technology and Mathematics Education KLAs are drawn. Students have to integrate and apply the knowledge and skills from the three KLAs in the process of conducting the project.

Procedures:

Preparation Stage

- Teachers briefed the students on the background and topic of the project. A video on healthy eating for teenagers is played to arouse students' interest of the topic and help them understand the purpose of conducting the project.
- Teachers of the three KLAs introduce/revise related learning elements during their lessons.
- Working in groups of four, students formulate their enquiry questions. They also discuss in groups and plan how to distribute the workload and conduct the project.

Implementation Stage

- Students collect the necessary information to build up their knowledge of the topic:
    - Some groups apply their IT skills to search for information from the Internet about food and diet, including the functions of various food substances, different nutritional values, recommended daily intake, etc.
    - Some groups apply their computational skills to calculate and analyse the nutritional values of different types of food.
    - One group even conducts a survey to collect information about the food preference of their fellow students, and prepare food samples for tasting.
- Each group discusses and designs their diet menu. Students also have to explain the choice of food in their diet menu based on the information collected. With their teachers' guidance, students learn how to acknowledge the source of information.

Concluding Stage

- After proper analysis, each group prepares the healthy diet menu. A presentation is made to the school lunch box supplier via arrangements made by their teachers. They explain the choice of food for a healthy school lunch box. They also raise questions, share their views and comment on other groups' products.

Example 7

Using Learning Journals to Develop Self-directed Learning Among Students

Level: Secondary 1 - 3 **Curriculum:** Science Education KLA

Emphasis: Self-learning skills, effective learning and teaching of science

Aims: To develop students' self-learning skills through using learning journals

Description:
A learning journal is a record of the progress of students' own learning. It may include a record of what the learner read, learned or investigated in the subject area, questions and thoughts that came up in the learner's mind, as well as the learner's own reflections on his/her learning process.

Writing learning journals can motivate students and develop self-directed learning among students both during the lessons and private study at home. With appropriate strategies in parallel, learning journals can also be used to embrace learner diversity and promote peer learning, and hence foster development of a learning culture among students. Students can learn more actively and effectively if they have a clearer picture of where they are and the ways to go. Writing learning journals also enables students to timely reflect on their own learning process, and facilitates development of a habit of evaluation and self-reflection among the students.

Strategies/Procedure:

1. During science lessons, teacher can guide students to:
   - jot notes or key points in their learning journals during lessons;
   - draw concept maps or use tables to summarise what they have learnt in science lessons;
   - write down questions that may arise during the learning process;
   - write down the tasks or problems that they may follow up or further investigate; and
   - exchange learning journals and seek for comments from peers.

2. Extended learning activities at home:
   - As a means to promote self-directed learning, students can propose tasks by themselves for completion at home in their learning journals. The tasks, e.g. reading scientific articles, making a simple model, solving a practical problem, etc., should be safe, easy to handle, interesting and related to the learning elements in the Science (S1 - 3) curriculum.

- Examples of tasks that students may propose in their learning journals:

Tasks	Examples
Write down the observations of some phenomena	The changes of an egg in vinegar for a few days
Record the results and draw conclusions on some simple scientific investigations proposed by teachers	Which fruit or vegetable can produce electricity to light up a LED?
Design and conduct simple scientific investigations by students themselves	What factor(s) can speed up the evaporation of water in a tissue paper?
Search for information of related topics	Information on applications of different gases
Summarise the content of some extended reading and write some notes to reflect the learning	Reading science/STEM related articles, books and news
Write down their reflection of learning	What students have learnt in the tasks? Is there any means to improve the learning effectiveness?

To embrace learner diversity, students are given flexibility to present their thought in ways that best fit their needs, e.g. brief notes, short paragraphs, tables, flow-charts, diagrams, photos, sketch graphs, etc.

3. Follow-up Action:
   - Teachers should skim through the learning journals of individual students and offer prompt feedback and comments to guide the students and help them improve.
   - By referring to their learning journals, students should be encouraged to present their thoughts and raise questions about issues related to their learning in class, with words of praise or appreciations provided by teachers and peers where appropriate. This arrangement can more effectively engage the students and their peers in learning, provide a chance for more in-depth reflection, develop a sense of ownership in one's learning and foster development of a habit of mind in self-reflection and solving problems.

Example 8

Integrating e-Learning Strategies into Practical Enquiry

Level: Secondary 4 - 6 **Curriculum:** Chemistry

Emphasis: e-learning, practical enquiry

Aim: (1) To facilitate students to actively participate in practical activities

(2) To promote collaboration among students

Description/Procedure:

A chemistry teacher, who is working in a school with a good Wi-Fi connection to the Internet[7], explains to his students in the laboratory how to carry out the four different practical learning tasks on the topic “Redox reaction” using a brief talk and a tailored-made experiment manual. As a routine practice, students organise themselves into different study groups, with each consisting of 4 or 5 students, to complete the tasks. Four laboratory benches equipped with necessary apparatus and materials for the tasks are already set by the laboratory technician. Each group of students is required to complete the practical tasks and video-record the whole processes with a narration.

In each group, students first read the experiment manual, discuss how to allocate duties and then carry out the practical tasks in a collaborative way. A student takes up the role of a video camera operator with a tablet computer provided by the school while another student serves as a narrator. The rest work together to prepare the chemicals and handle the apparatus for the task. After a brief group discussion, all students start to carry out the tasks assigned. The whole process is video-recorded with a narration. The teacher moves around in the laboratory to provide learning support to different groups wherever necessary.

[7] The school is one of the first 100 public sector schools participated in the “Support Scheme for e-Learning in Schools” (EDB, 2014). (www.edb.gov.hk/en/edu-system/primary-secondary/applicable-to-primary-secondary/it-in-edu/supportscheme/index.html)

Soon after completion of the practical tasks, students start to upload the video clips to a learning management system (LMS)[8], which is provided by a local tertiary institute for this school.

When all groups have completed the practical tasks, the teacher leads a post-enquiry debriefing session to consolidate students' learning in the lesson. The teacher first retrieves the video clips produced by the students from the LMS, and then launches an interactive question and answer session. During the dialogue, the teacher provides quality and timely feedback to the students. After discussion, students are encouraged to work collaboratively to review their observations and answers by referring to the video clips again in the LMS. Finally, each student needs to complete an individual report. By the end of the lesson, the teacher encourages his students to review all the video clips again in the LMS at any time and any place after the lesson whenever necessary.

Remarks:

This lesson requires IT resources and support, for example, a good Internet connection, several tablet computers and a LMS, as well as the support from a laboratory technician. The following points are considered to be important success criteria and features that are conducive to students' learning.

- The teacher has developed a good lesson plan with detailed elaboration of major steps and time allocation.
- The students engage actively in doing, observing, recording and narrating the experiments, and engaging in quality dialogue in the debriefing session.
- The teacher provides quality and timely feedback to students by referring to the video clips produced by the students and saved in the LMS.
- The students can access all the video clips in the LMS at any time and any place again via the Internet.

[8] MDM Partnership Programme (HKU, 2015) (elearning.eee.hku.hk/)

Example 9

Using Mobile Apps for Investigative Study in Physics

Level: Secondary 4 - 6 **Curriculum:** Physics

Emphasis: IT, investigative study

Aim: To promote investigative study of physical phenomena among students by using easily accessible IT equipment and freeware

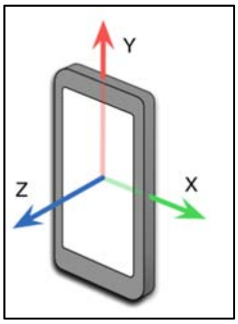
Introduction:

Mobile devices, which include smartphones and tablet computers, have become popular IT tools to facilitate learning and teaching. These mobile devices are usually equipped with a number of sensors (or transducers): accelerometers, a field strength sensor, a light intensity sensor, a GPS receiver, etc. Mobile devices coupled with the embedded sensors and appropriate software (usually called "applications" or simply "apps") can be used as data loggers for physics experiments.

<u>Task 1</u> – Studying the motion of a free falling object

Background:

In this task, students try to investigate the free fall of an object by using the accelerometers in asmartphone. Students need to realise that three sensors positioned to detect motions along the x, y, and z planes are available in the smartphone (Figure d). The smartphone should be properly oriented during the process. This task is preferably done as a team so that students may discuss about the means to protect the smartphones and to collect data accurately. This task presents students with lots of intriguing questions, such as "How the smartphone should be held before dropping?" and "Which axis is measuring acceleration due to gravity?". Students need to determine an appropriate sampling frequency for measurement, the dependent and independent variables, a graph to show the relationship between falling time and falling distance, and estimate the acceleration of gravity *g* from the graph.



<u>Figure d</u>

Procedure:

There are many different ways of performing the experiment. One possible way of investigating the Physics of free fall is to suspend the smartphone from a thin piece of string, which is cut apart to start the fall. To avoid damaging the device, students should place a soft mat (e.g. a cushion) on the floor for the smartphone to land on. The smartphone serves dual functions in this experiment. It serves both as a falling body itself and also as an electronic timer (more precisely, a data logger), making it possible to determine the falling time against the height with very high accuracy. Students need to identify the portion of the graph representing free fall in this experiment.

<u>Task 2</u> – Studying the motion of an elevator

Background:

Traditional “elevator” problems in Physics require students to study the forces acting on a person or an object while it is accelerating up or down. The understanding of the variation of the acceleration and also the resultant force versus time could be fostered by simply using a mobile device and a suitable app. In this task, students can investigate the change in acceleration and force on them as they move from one floor to another and come to rest in an elevator.

Procedure:

A common misconception among students is that an elevator moving upward—even at constant velocity—needs a net upward force to keep it in motion. After performing the experiment, students can base on the actual graph obtained (Figure e) and clarify their misunderstanding, if any, about the motion of an elevator from the experimental results. Students need to relate different sessions of an elevator ride (i.e., accelerating/decelerating or constant velocity) to relevant portions of the graph.

<u>Figure e</u>

While students are encouraged to work collaboratively to discuss about their observations and interpret the data and the graphs, each student is required to submit a report at the end. To embrace learner diversity, the more able students can be asked to investigate, based on the acceleration-time graph, how the velocity varies with time and the total distance travelled by the elevator. If necessary, raw data may be extracted from the mobile devices for more detailed analysis by spreadsheets or other mathematical software.

Other points to note:

- Mobile devices with accelerometers embedded are versatile tools for investigative study of mechanical motion in Physics. With variations in setup, they can be used to study projectile motion, collision, circular motion, oscillations and even motion in a fluid.
- Free-of-charge mobile apps are available in the market to measure the acceleration of an object by using the embedded accelerometer. To further enhance cross-disciplinary learning of science, technology and mathematics in schools, Physics teachers can collaborate with Technology/Mathematics teachers and guide the more able students to develop their own apps to invoke the accelerometers and customise the user interface, controls, data sampling rate, output, etc. in a way that best meets the unique challenges of a particular investigation.

Example 10

Design and Make a Model of the Aorta with Artificial Heart Valve

Level: Secondary 4 - 6 **Curriculum:** Biology

Emphasis: STEM education

Aims: To enhance students' understanding of the functioning of heart valve through designing and making a model

In this activity, students will work in groups to go through the "design and make" process like a bioengineer to solve problem of an authentic scenario.

Before carrying out this activity, students should have sufficient background knowledge about the circulatory system in humans, including the structure and functions of the heart and the heart valves, composition of blood and the way blood flow in the heart.

Teachers may guide students in this activity by using the 5E Instructional Model[9].

Stage 1 – Engagement

Students are given an authentic scenario in which doctors and bioengineers work together to help patients with a diseased aortic valve. For these patients, the aortic valve does not close tightly and blood will flow back into the heart; and the valve does not open wide enough to allow all the blood to leave the heart. To help these patients to live longer and have healthier lives, replacements of their flawed aortic valves with artificial ones are needed. In this activity, students are asked to design and make a model of an aorta with an artificial heart valve.

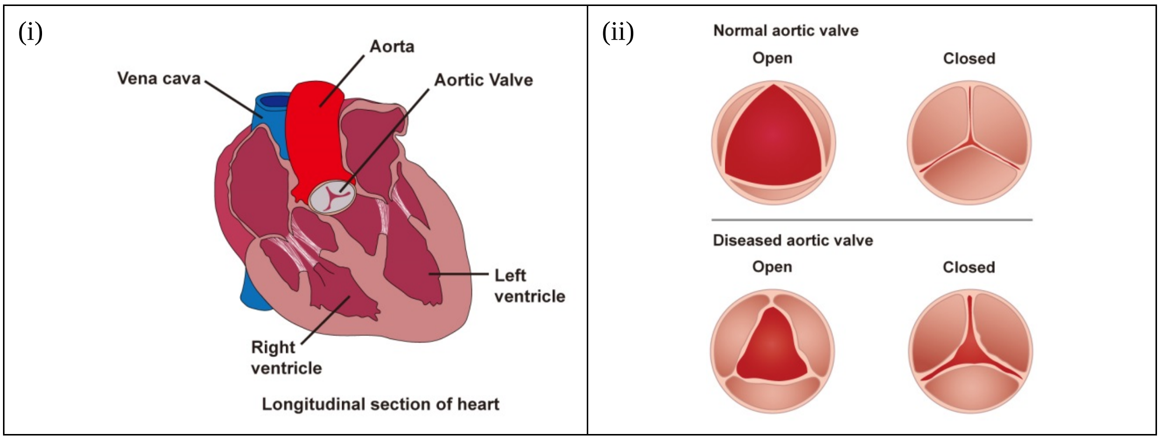


Figure f (i) Position of the aortic valve in the heart.
(ii) The normal and diseased aortic valve when they are open and closed.

[9] 5E Instructional Model refers to the five instructional phases proposed by Biological Sciences Curriculum Study (BSCS). The five phases includes engagement, exploration, explanation, elaboration and evaluation.

Stage 2 – Exploration

Teachers introduce some examples of materials to be used (as shown in Figure g). Each group of students discusses among themselves to propose some designs of the model and make models with the materials given.

Figure g Examples of materials (adhesive tape, marbles, twisting ties, paper clips, modeling clay, surgical gloves and transparent plastic tubes).

As the models to be made have to simulate the function of heart valves, that is allowing blood flow in the heart quickly in one direction only and preventing the backflow of blood, students have to test their models for water flow to see whether the models function in a similar way. Teachers may set some design requirements for the models. For instance, the models should:

- allowing water to pass through in one direction with a fast enough flow rate (e.g. about 500 ml per 30 seconds); and
- stopping water to flow/only allowing water to flow very slowly in the other direction.

Stage 3 - Explanation

Students present in class their models and explain the working principle of their models by annotated diagrams.

Stage 4 - Elaboration

Students are asked to propose ways for improving the design of their models. They have to refine their models or make new models, and test them for water flow again. Students have to write a report on how they set up the models, test for their functions, and record the data as appropriate.

Two examples of the models are shown in Figures h & i and an example of the setup for testing the functioning of the model is shown in Figure j.

(a) (b) (c)

Figure h An example of model constructed with transparent plastic tubes, paper clips, marbles and surgical gloves.

(a) Two paper clips were bent to make a cross-shape cage to trap a marble and then put inside a transparent plastic tube.
(b) A “glove finger” with a hole cut at its tip was fit onto one end of another transparent plastic tube.
(c) The two tubes were joined together.

(a) (b) (c)

Figure i Another example of model constructed with transparent plastic tubes, paper clips, marbles and modeling clay.

(a) Two paper clips were bent to make a cross-shape cage to trap a marble and then put inside a transparent plastic tube.
(b) A piece of modeling clay was moulded and stuck to the mouth of one end of another transparent plastic tube to narrow its mouth.
(c) The two tubes were joined together.

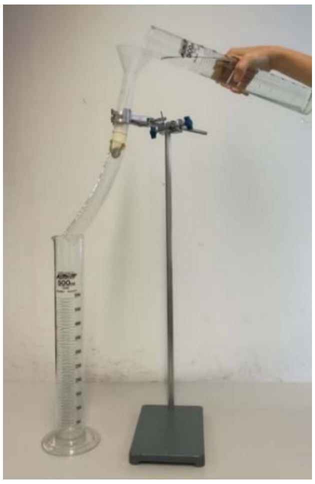


Figure j A set-up for measuring the flow rate of water through the model of aorta with artificial heart valve.

Stage 5 - Evaluation

Students are asked to evaluate the models of aorta with artificial heart valves. They may set a scoring rubric themselves to evaluate the models through self-assessment or peer assessment.

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Appendices

Appendices

Seven Learning Goals of the Primary and Secondary Education

The two sets of learning goals for the primary and secondary education updated in 2014 and 2017 respectively to respond to the latest changes from a natural continuum of progressive milestones that students are expected to achieve upon completion of the two levels of education based on the seven areas covering knowledge, skills, and values and attitudes for lifelong learning and whole-person development. The learning goals at the two levels are defined using slightly different diction and sequences due to consideration of the students' developmental and growth needs and learning experiences.

Updated Seven Learning Goals of Secondary Education

To enable students to:

- become an informed and responsible citizen with a sense of national and global identity, appreciation of positive values and attitudes as well as Chinese culture, and respect for pluralism in society
- acquire and construct a broad and solid knowledge base, and to understand contemporary issues that may impact on students' daily lives at personal, community, national and global levels
- be proficient in biliterate and trilingual communication for better study and life
- develop and apply generic skills in an integrative manner, and to become an independent and self-directed student for future study and work
- use information and information technology ethically, flexibly and effectively
- understand one's own interests, aptitudes and abilities, and to develop and reflect upon personal goals with aspirations for further studies and future career
- To lead a healthy lifestyle with active participation in physical and aesthetic activities, and to appreciate sports and the arts

Secondary Education Curriculum Guide (2017)

Seven Learning Goals of Primary Education

Students are expected to achieve upon completion of primary education:

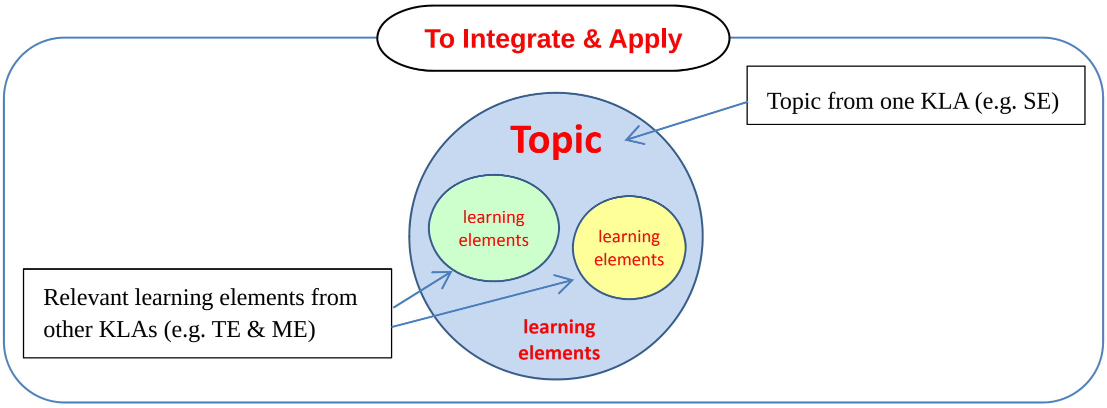
1. Know how to distinguish right from wrong, fulfil their duties as members in the family, society and the nation, and show acceptance and tolerance towards pluralistic values;
2. Understand their national identity and be concerned about society, the nation and the world, and to fulfil their role as a responsible citizen;
3. Develop an interest in reading extensively and cultivate a habit of reading;
4. Actively communicate with others in English and Chinese (including Putonghua);
5. Develop independent learning skills, especially self-management skills and collaboration skills;
6. Master the basics of the eight Key Learning Areas to prepare for studying in secondary schools; and
7. Lead a healthy lifestyle and develop an interest in aesthetic and physical activities and an ability to appreciate these activities.

Basic Education Curriculum Guide (Primary 1 - 6) (2014)

Approaches to Organising Learning Activities on STEM Education

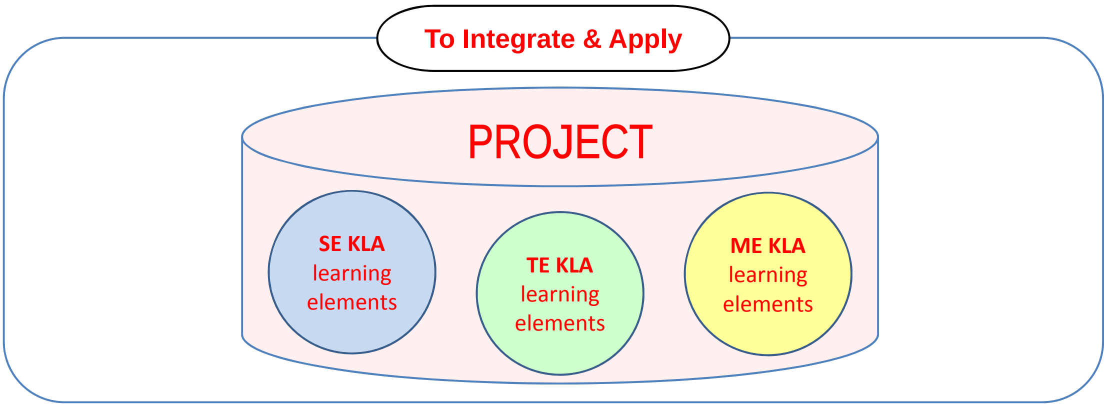
Approach One

Learning activities based on topics of a KLA for students to integrate relevant learning elements from other KLAs



Approach Two

Projects for students to integrate relevant learning elements from different KLAs



List of the EDB Online Resource Materials to Support Curriculum Development and Learning and Teaching of Science

(as at April 2017)

Title		Website
1.	Online English-Chinese Glossaries of Terms Commonly Used in the Teaching of Science Subjects in Secondary Schools 線上中學科學科目常用英漢辭彙	*cd1.edb.hkedcity.net/cd/science/glossarysci.html*
2.	English-Chinese Glossaries of Terms Commonly Used in the Teaching of Biology, Chemistry, Physics and Science (S1-3) in Secondary Schools 中學生物科、化學科、物理科和科學科（中一至中三）常用英漢辭彙	*www.edb.gov.hk/en/curriculum-development/kla/science-edu/ref-and-resources/glossary.html*
3.	Atomic World 原子世界	*www.hk-phy.org/atomic_world/*
4.	Chemistry Experimental Techniques 化學實驗技巧	*minisite.proj.hkedcity.net/chemtech/cht/index.html*
5.	Contextual Physics 情境物理	*http://www.hk-phy.org/contextual/*
6.	EDB One-stop Portal for Learning & Teaching Resources (Science Education) 教育局一站式學與教資源平台（科學科教育）	*minisite.proj.hkedcity.net/edbosp-sci/eng/home.html* *minisite.proj.hkedcity.net/edbosp-sci/cht/home.html*
7.	EDB One-stop Portal for Learning & Teaching Resources (General Studies) 教育局一站式學與教資源平台（小學常識科）	*minisite.proj.hkedcity.net/edbosp-gs/eng/home.html* *minisite.proj.hkedcity.net/edbosp-gs/cht/home.html*
8.	Educational Television (ETV) 教育電視	*etv.edb.gov.hk/*
9.	Energy Efficiency 能源效益	*www.hk-phy.org/energy/index_e.html* *www.hk-phy.org/energy/index_c.html*
10.	ETV – Investigative Study in Physics in the New Senior Secondary Science Curriculum (Student version) 教育電視 – 新高中物理科探究研習 （學生篇）	*www.hkedcity.net/etv/resource/780251301* *www.hkedcity.net/etv/resource/1139923892*

	Title	Website
11.	Exercises on Structure Determination of Organic Compounds (Mass Spectrometry) 有機化合物的結構測定	*cd1.edb.hkedcity.net/cd/science/chemistry/s67chem/references/MS_Eng2005_Questions.pdf* *cd1.edb.hkedcity.net/cd/science/chemistry/s67chem/references/MS_Chi2005_Questions.pdf*
12.	Furniture and Equipment List for New Schools（此頁內容不提供中文版本） 新建校舍家具及設備一覽表	*www.edb.gov.hk/en/sch-admin/sch-premises-info/furniture-equipment/primary-secondary-schools.html*
13.	General Studies for Primary Schools 小學常識科	*www.edb.gov.hk/tc/curriculum-development/kla/general-studies-for-primary/index.html*
14.	Guidelines on the Prevention of Blood-borne Diseases in Schools 血液傳染病在校內預防指引	*www.info.gov.hk/aids/pdf/g103.pdf* *www.info.gov.hk/aids/pdf/g102.pdf*
15.	HKedCity: Resources Depository 香港教育城：教學資源庫	*resources.hkedcity.net/*
16.	Implementing Sex Education through the Junior Secondary Science Curriculum 透過初中科學科課程推行性教育	*cd1.edb.hkedcity.net/cd/science/is/SexEducation/SexEducation_e.pdf* *cd1.edb.hkedcity.net/cd/science/is/SexEducation/SexEducation_c.pdf*
17.	Investigative Study in Chemistry - Exemplars of Learning and Teaching Activities 化學的探究研習—學習活動示例	*cd1.edb.hkedcity.net/cd/science/chemistry/nss/is/nss_is_eng.pdf* *cd1.edb.hkedcity.net/cd/science/chemistry/nss/is/nss_is_chi.pdf*
18.	Learning and Teaching Exemplar for Medical Physics 醫學物理學學與教範例	*www.hkedcity.net/article/project/medicalphysics/*
19.	Contextual Physics in Ocean Park 情境物理之海洋公園	*www.hk-phy.org/oceanpark/*
20.	Physics World 物理園	*www.hk-phy.org/*
21.	Promoting the Quality of Chemistry Learning with Active Reading and Writing Tasks - Exemplars of Learning & Teaching Activities *(Password required)* 促進化學科學習的閱讀及寫作計畫 - 學習活動示例*（需要密碼登入）*	*cd1.edb.hkedcity.net/cd/science/chemistry/zipfile/active_rw.zip*

Title		Website
22.	Reaction Mechanism Animation 反應機理動畫	*cd1.edb.hkedcity.net/cd/science/chemistry/mech_e/Tutorial_29092007.swf* *cd1.edb.hkedcity.net/cd/science/chemistry/mech_c/Tutorial_05c.swf*
23.	Reactions of Metals 金屬之反應	*cd1.edb.hkedcity.net/cd/science/chemistry/resource/reactions/main.html*
24.	Enhancing Science Learning Through Electronic Library 促進學生學習科學的網上文章	*resources.edb.gov.hk/physics/index_c.html* *resources.edb.gov.hk/physics/index_e.html*
25.	Recommended Textbook List, EDB 適用書目表—教育局	*cd.edb.gov.hk/rtl/search.asp*
26.	Resources Depository - ETV 教學資源庫—教育電視	*www.hkedcity.net/etv/en/* *resources.hkedcity.net/etv/*
27.	Safety in Science Laboratories 科學實驗室安全手冊	*cd1.edb.hkedcity.net/cd/science/laboratory/safety/SafetyHandbook2013_English.pdf* *cd1.edb.hkedcity.net/cd/science/laboratory/safety/SafetyHandbook2013_Chinese.pdf*
28.	Science Education - Laboratory Safety and Management 實驗室安全及管理	*www.edb.gov.hk/en/curriculum-development/kla/science-edu/ref-and-resources/lab-safety-and-management.html* *www.edb.gov.hk/tc/curriculum-development/kla/science-edu/ref-and-resources/lab-safety-and-management.html*
29.	Science Education, EDB 教育局科學教育	*www.edb.gov.hk/en/curriculum-development/kla/science-edu/index.html*
30.	Science Laboratories – Fixtures & Furniture 科學實驗室裝置及家具	*cd1.edb.hkedcity.net/cd/science/laboratory/layout/fixfur95.pdf*
31.	Teachers Professional Development and Resources Sharing Platform (Biology) 教師專業發展及資源共享平台（生物科）	*edblog.hkedcity.net/nssbio*
32.	Teachers Professional Development and Resources Sharing Platform (Chemistry) 教師專業發展及資源共享平台（化學科）	*edblog.hkedcity.net/nsschem*

	Title	Website
33.	Teachers Professional Development and Resources Sharing Platform (Physics) 教師專業發展及資源共享平台（物理科）	*edblog.hkedcity.net/cdiphysics*
34.	Teachers Professional Development and Resources Sharing Platform (Science) 教師專業發展及資源共享平台（科學科）	*edblog.hkedcity.net/scienceteaching/*
35.	Integrated Science (S4-6) 綜合科學（中四至中六）	*cd1.edb.hkedcity.net/cd/science/is4to6/index_e.html*
36.	The Integrated Science (S4-6) Teacher Sharing Platform 綜合科學科（中四至中六）教師交流平台	*edblog.hkedcity.net/is4to6*
37.	Using Datalogger in the Teaching of Physics 運用數據收集器於物理科學教學	*data-log.hkedcity.net/index.shtml* *data-log.hkedcity.net/physicsc/index.shtml*
38.	Visualising Chemistry 智趣化學	*cd1.edb.hkedcity.net/cd/science/chemistry/resource/vc/index.html*
39.	Writing and Application of Physics Specific Genres 物理科專科語體答題及應用	*edb.hkedcity.net/phygenres/en/index.htm* *edb.hkedcity.net/phygenres/zh/index.htm*
40.	Writing with Chemistry Specific Genres 化學科專科語體寫作	*ifile.hkedcity.net/1/001/926/genre/*
41.	小學常識科教學資源庫 日常生活中的科學與科技	*www.hkedcity.net/edb/teachingresources/category.php?site_key=gs&categoryId=11*
42.	「常識百搭」小學 STEM 探究展覽	*www.hkedcity.net/ises/cht/archive.html*
43.	教育電視—教學資源庫（科學教育）	*www.hkedcity.net/etv/listing/5707715ef57da1023c000000*
44.	教育電視—教學資源庫（小學常識科）	*www.hkedcity.net/etv/listing/57077123f57da1f03b030000*
45.	教育電視—高中化學探究研習	*www.hkedcity.net/etv/resource/207401800*
46.	The “Bright” Future of Scientific Research 科研之光	*www.hkedcity.net/etv/resource/11957752*

Title		Website
47.	The Future of Rice 米的未來	*www.hkedcity.net/etv/resource/2084914033*
48.	Soybean Homecoming 大豆回家	*www.hkedcity.net/etv/resource/1564245470*
49.	A New Dimension of Communication 通訊新領域	*www.hkedcity.net/etv/resource/19010548*
50.	Safety in Exploring Science 科學探索的安全守則	*resources.edb.gov.hk/~ses/* *resources.edb.gov.hk/~ses/index_b5.html*

Appendix 4

Community Resources for Science Education

List of organisations that can provide community resources to support science education:

Title		Website
1.	AFCD Lions Nature Education Centre	*www.afcd.gov.hk/english/country/cou_lea/cou_lea_ven/lions.html*
2.	STEM Education Centre	*www.atec.edu.hk/stemcentre*
3.	Caritas Chan Chun Ha Field Studies Centre	*caritasfsc.edu.hk/tc/*
4.	CLP Power Hong Kong	*www.clp.com.hk/zh*
5.	Ho Koon Nature Education cum Astronomical Centre	*www.hokoon.edu.hk/en/main.html*
6.	Hong Kong Country Parks	*www.afcd.gov.hk/english/country/cou_vis/cou_vis_cou/cou_vis_cou.html*
7.	Hong Kong Global Geopark of China	*www.geopark.gov.hk/en_index.htm*
8.	Hong Kong Observatory	*www.hko.gov.hk/contentc.htm*
9.	Hong Kong Productivity Council	*www.hkpc.org/zh-HK/*
10.	Hong Kong Science Museum	*hk.science.museum/zh_TW/web/scm/index.html*
11.	Hong Kong Science and Technology Parks	*www.hkstp.org/en/index.aspx*
12.	Hong Kong Space Museum	*www.lcsd.gov.hk/CE/Museum/Space/zh_TW/web/spm/whatsnew.html*
13.	Hong Kong Wetland Park	*www.wetlandpark.gov.hk/en/*
14.	Water Supplies Department	*www.wsd.gov.hk/en/education/educational_visits_to_water_treatment_works/index.html*
15.	Aviation Discovery Centre	*www.hongkongairport.com/eng/shopping/entertainment/t2/aviat/avia.html*
16.	Hong Kong Association for Science and Mathematics Education	*www.hkasme.org/*
17.	Hong Kong Federation of Youth Groups	*www.hkfyg.org.hk/*
18.	Hong Kong Technology Education Association	*www.hktea.org/*

Title		Website
19.	Jockey Club Museum of Climate Change (MoCC)	*www.gaia.cuhk.edu.hk/MoCC/*
20.	Kadoorie Farm & Botanic Garden	*www.kfbg.org/eng/*
21.	Ocean Park Academy Hong Kong	*opahk.oceanpark.com.hk/en/*
22.	Sik Sik Yuen Biotechnology Mobile Laboratory Program	*mobilelab.hoyu.edu.hk/*
23.	The Hong Kong Academy of Gifted Education	*www.hkage.org.hk/*
24.	WWF The Mai Po Nature Reserve	*www.wwf.org.hk/en/*
25.	Young Entrepreneurs Development Council (YDC)	*www.edb.gov.hk/en/sch-admin/admin/about-sch/bspp/scp.html* *scp.ydc.org.hk/e/default_home.asp*

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Membership List

Membership of Curriculum Development Council Committee on Science Education

(from September 2014 to August 2017)

Chairperson:	Mr. LAU Kwok-leung TWGHs Wong Fung Ling College	(from 1.9.2014 to 31.8.2015)
	Dr. CHENG Kin-tak, Samuel United Christian College (Kowloon East)	(from 1.9.2015 to 31.8.2017)
Vice-chairperson:	Mr. CHEUK Wai-kar Curriculum Development Institute, EDB	(from 20.10.2014 to 31.5.2015)
	Dr. FONG Wai-hung, Raymond Curriculum Development Institute, EDB	(from 1.6.2015 to 14.7.2015)
	Ms. TSE Yuen-ching, Edith Curriculum Development Institute, EDB	(from 15.7.2015 to 31.8.2017)
Members from Tertiary Institutions:	Prof. CHAN Wai-kin Department of Chemistry, The University of Hong Kong	(from 1.9.2014 to 31.8.2017)
	Prof. HUI Pak-ming Department of Physics, The Chinese University of Hong Kong	(from 1.9.2014 to 31.8.2015)
	Prof. SO Wing-mui, Winnie Department of Science and Environmental Studies, The Hong Kong Institute of Education	(from 1.9.2014 to 31.8.2015)
	Prof. CHENG May-hung, May Department of Curriculum and Instruction, The Hong Kong Institute of Education (from 1.9.2015) / The Education University of Hong Kong (from 27.5.2016 onward)	(from 1.9.2015 to 31.8.2017)
	Prof. LEUNG Pak-wo Department of Physics, The Hong Kong University of Science and Technology	(from 1.9.2015 to 31.8.2017)
Members from Related Professional Bodies or Related Fields:	Mr. LEUNG Wai-ming, Robert Hong Kong Space Museum	(from 1.9.2014 to 31.8.2017)
	Mr. WONG Wing-kei Hong Kong Association for Science and Mathematics Education	(from 1.9.2014 to 31.8.2017)

Members from CDCC on Special Educational Needs:	Mr. SAE-LIM, Premin Caritas Pelletier School	(from 1.9.2014 to 31.8.2015)
	Mr. FUNG Sui-hing China Holiness Church Living Spirit College	(from 1.9.2015 to 31.8.2017)
School Heads:	Dr. CHENG Kin-tak, Samuel United Christian College (Kowloon East)	(from 1.9.2014 to 31.8.2015)
	Mr. LO Wai-shing, Vincent Evangel College	(from 1.9.2014 to 31.8.2017)
	Mr. MA Yuen-fat Henrietta Secondary School	(from 1.9.2014 to 31.8.2015)
	Mr. CHOI Chi-chiu, Hubert TWGHs Chen Zao Men College	(from 1.9.2015 to 31.8.2015)
	Dr. LEUNG Kin-man Kiangsu-Chekiang College (Kwai Chung)	(from 1.9.2015 to 31.8.2017)
	Mr. WAN Ka-kit Baptist Lui Ming Choi Secondary School	(from 1.9.2016 to 31.8.2017)
School Teachers:	Ms. CHEUNG Tung-ping Munsang College	(from 1.9.2014 to 31.8.2015)
	Ms. HO Wing-sze, Teresa ELCHK Lutheran Secondary School	(from 1.9.2014 to 31.8.2015)
	Dr. LAU Sui-yee Tsuen Wan Ho Chuen Yiu Memorial College	(from 1.9.2014 to 31.8.2017)
	Mr. PUN Kwong-cheung SKH Tsang Shiu Tim Secondary School	(from 1.9.2014 to 31.8.2015)
	Dr. WONG Tsz-wing Pui Ching Middle School	(from 1.9.2014 to 31.8.2017)
	Mr. YING Pui-chi, Bosco Shun Tak Fraternal Association Leung Kau Kui College	(from 1.9.2014 to 31.8.2015)
	Ms. CHAN Hoi-yan HKTA The Yuen Yuen Institute No. 3 Secondary School	(from 1.9.2015 to 31.8.2017)
	Mr. CHEUNG Chak-man Cognitio College (HK)	(from 1.9.2015 to 31.8.2017)

	Mr. HUI Ting-kwok Buddhist Wing Yan School	(from 1.9.2015 to 31.8.2017)
	Dr. SUEN Ka-chun Po Leung Kuk Laws Foundation College	(from 1.9.2015 to 31.8.2017)
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	Mr. SZETO Yuk-tong Hong Kong Examinations and Assessment Authority	(from 1.9.2014 to 31.8.2017)
Secretaries:	Mr. CHOI Chit-kai, Willy Curriculum Development Institute, EDB	(from 1.9.2014 to 31.8.2015)
	Ms. TSOI Lee-man Curriculum Development Institute, EDB	(from 1.9.2015 to 31.8.2016)
	Dr. FONG Wai-hung, Raymond Curriculum Development Institute, EDB	(from 1.9.2016 to 31.8.2017)