SCIENCE (BIOLOGY) SYLLABUS

Upper Secondary
Normal (Academic) Course

Implementation starting with
2023 Secondary Three Cohort

Ministry of Education
SINGAPORE

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SECTION 1: INTRODUCTION

1. INTRODUCTION

1.1 Science Curriculum Framework

The *Science Curriculum Framework* (see **Figure 1.1**) encapsulates the thrust of science education in Singapore, which is to provide students with a strong foundation in science for life, future learning, citizenry and work.

Science for Life and Society at the core of the curriculum framework captures the essence of the goals of science education.

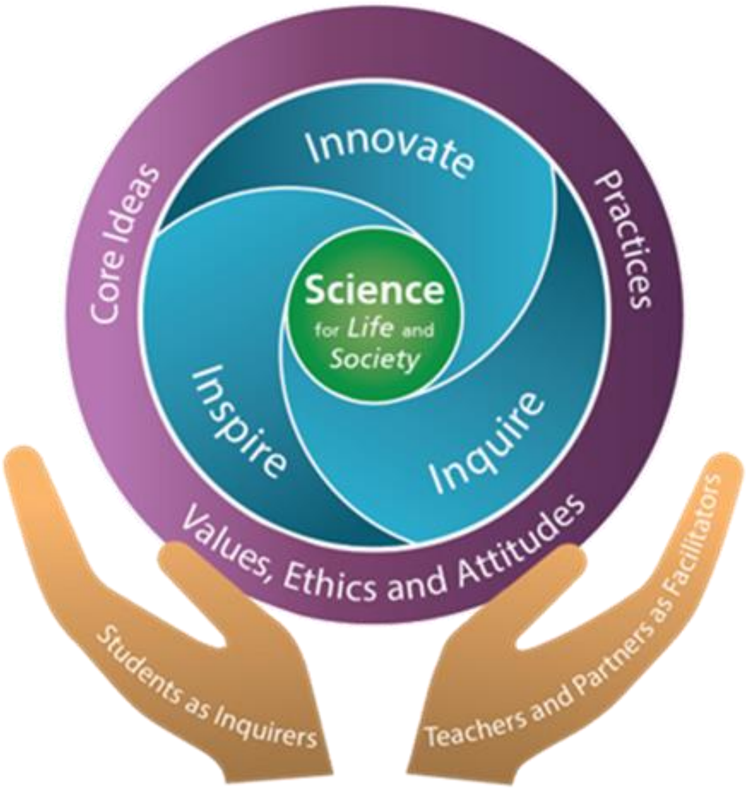

Figure 1.1: Science Curriculum Framework

Our science students are diverse, with different needs, interests and aptitudes for science. Given the diversity of our students and the needs of our country, the twin **goals of science education** are:

- To enthuse and nurture all students to be scientifically literate, which can help them to make informed decisions and take responsible actions in their daily lives.

- To provide strong science foundations for students to innovate and pursue STEM for future learning and work.

Surrounding the core of the framework are the three "IN"s, *inspire*, *inquire* and *innovate,* which represent the **vision of science education**. It encapsulates the desired overall experience of our students in science education:

- INspired by science. Students enjoy learning science and are fascinated by how everyday phenomena have scientific connections and how science helps solve many of our global challenges. They regard science as relevant and meaningful, and appreciate how science and technology have transformed the world and improved our lives. A good number of students see science-related careers as a viable profession to serve the good of society.

- INquire like scientists. Students have a strong foundation in science, and possess the spirit of scientific inquiry. They are able to engage confidently in the Practices grounded in the knowledge, issues and questions that relate to the roles played by science in daily life, society and the environment. They can discern, weigh alternatives and evaluate claims and ideas critically, based on logical scientific evidence and arguments, and yet be able to suspend judgement where there is lack of evidence.

- INnovate using science. Students apply and experience the potential of science to generate creative solutions to solve a wide range of real-world problems, ranging from those affecting everyday lives to complex problems affecting humanity. A strong pipeline of students can contribute towards STEM research, innovation and enterprise.

The outer ring represents the domains that make up the strong science fundamentals: *Core Ideas* of science, *Practices of Science*, and *Values, Ethics and Attitudes* in science.

- Core Ideas. Core Ideas are the distilled ideas central to the discipline. The Core Ideas help students see the coherence and conceptual links *across* and *within* the different sub-disciplines of science (i.e. biology, chemistry and physics).

- Practices of Science (POS). The Practices consist of three components:
  (a) Demonstrating Ways of Thinking and Doing in Science (WOTD);
  (b) Understanding the Nature of Scientific Knowledge (NOS); and
  (c) Relating Science, Technology, Society and Environment (STSE).

  They represent the set of established procedures and practices associated with scientific inquiry, what scientific knowledge is and how it is generated and established, as well as how science is applied in society. The Practices serve to highlight that the discipline of science is more than the acquisition of a body of knowledge (e.g. scientific facts, concepts, laws, and theories); it is also a *way of thinking and doing*. In particular, it is important to appreciate that the three components representing the cognitive, epistemic and social aspects of the Practices are intricately related.

- Values, Ethics and Attitudes (VEA) in Science. Although science uses objective methods to arrive at evidence-based conclusions, it is in fact a human enterprise conducted in particular social contexts which involves consideration of values and ethics. It is important for our students to be aware of and appreciate the values and ethical implications of the application of science in society. Thus, science education needs to equip students with the ability to articulate their ethical stance as they participate in discussions about socio-scientific issues that involve ethical dilemmas, with no single right answers.

The pair of hands in the Science Curriculum Framework represents the roles of students *as inquirers* in their learning and pursuit of science, supported by *teachers and partners as facilitators* of the students' learning experiences, to impart the excitement and value of science to the students. The partnership of learning and teaching goes beyond the students and teachers to include other partners who can facilitate learning in various contexts to help fuel students' sense of inquiry and innovation, to inspire them and to help them appreciate the application of science in their daily lives, society and the environment.

1.2 21st Century Competencies Framework

The *Framework for 21st Century Competencies and Student Outcomes* (see **Figure 1.2**) helps guide us to prepare our students to be confident people, self-directed learners, concerned citizens and active contributors – attributes we strive to develop in students to thrive in and contribute to a fast-changing and globalised world of the 21st century.

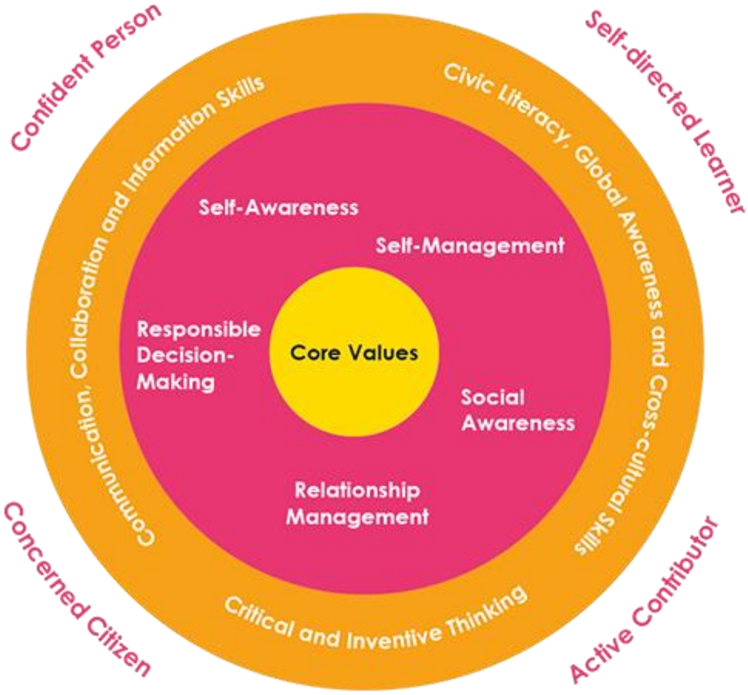

Figure 1.2: Framework for 21st Century Competencies and Student Outcomes

This framework identifies the core values, Social and Emotional Competencies, as well as competencies necessary for the globalised world we live in. In totality, these are referred to as 21st Century Competencies (21CC).

<u>**Supporting the Development of 21CC through Science**</u>

Science education plays an important role in helping our students understand and address many of the local and global challenges we face in the 21st century. These challenges include climate change, depletion of natural resources, disruptive innovations in technology (e.g. artificial intelligence), and feeding an increasing population. To navigate these challenges, we need to develop scientifically literate citizens who

- possess mindsets and practical knowledge of science and its applications to make informed decisions and responsible actions in their daily lives.

- appreciate science as humanity's intellectual and cultural heritage, the beauty and power of its ideas, as well as participate in socio-scientific issues ethically and in an informed manner.

- are able to apply scientific knowledge and skills, as well as adopt scientific attitudes and mindsets to innovate and push new frontiers.

In this respect, the development of scientific literacy supports MOE's efforts on the development of students' 21CC. As discussed in **Section 1.1**, the development of scientific literacy is necessary to equip students with strong science fundamentals in the three domains of Core Ideas, Practices, and Values, Ethics and Attitudes. The subsequent paragraphs illustrate ideas on how 21CC can be developed through the science curriculum.

Civic Literacy, Global Awareness and Cross-Cultural Skills (CGC)

For students to actively contribute to the community and nation, and develop an awareness of and the ability to analyse global issues and trends, they could be given opportunities to

- explore how science and technology contribute to society, in Singapore and globally, e.g. how applications of new scientific discoveries inspire technological advancements, and motivate scientists to ask new questions in their inquiry.

- participate in ethical discussions that require them to be open-minded when weighing multiple perspectives and develop in them a sense of responsibility for the environment.

Critical and Inventive Thinking (CIT)

For students to generate novel ideas to address issues and solve problems, exercise sound reasoning, use metacognition to make good decisions, and manage complexities and ambiguities, they could be given opportunities to

- engage in the process of inquiry. Students could raise divergent questions about the natural world, develop multiple ways to observe and collect evidence, and explore more than one explanation from their evidence. At the same time, students should exercise healthy scepticism in questioning the assumptions and uncertainties in their evidence and evaluate how these assumptions could influence their explanations.

- recognise that science is an evidence-based, model-building enterprise to understand the natural world through exploring how and why scientific models evolve over time in light of new evidence.

Communication, Collaboration and Information Skills (CCI)

For students to be able to communicate information and ideas clearly, collaborate effectively and manage information thoughtfully and responsibly, they could be given opportunities to

- communicate their ideas clearly and persuasively using the language of science. Students could engage in activities that allow them to express their appreciation for the need and importance of having scientific standards and terminology.

- understand how science is presented in various forms (e.g. orally, written, visual) and media (e.g. print media, social media) and evaluate the effect these forms of communication have on the audience (e.g. identifying fake news).

- collaborate with other students in knowledge construction. Students should present their work and ideas to others, and have healthy discussions and critique. Through collaborative discussions, students could develop social awareness as they are required to discern different perspectives, recognise and appreciate diversity, empathise with and respect others.

1.3 Purpose and Value of Biology Education

Biology is the study of life and hence, biology education provides a foundational understanding about the organisation and interactions at organismal, physiological and molecular levels. It develops in students a scientific mind and disposition, while addressing the broader questions of what life is and how life is sustained. Biological knowledge, skills and understanding allow us to tackle real-world challenges relating to climate change, energy, food, health and disease.

The study of biology is cognisant of the vast amounts of Life Sciences knowledge in the on-going biological revolution, which is driven by the evolving nature of biological knowledge and emergence of new biological fields. As such, the study of biology is stimulating, ethical and interesting, where taking action to care for the local and global environment is inherent to the nature of the subject.

In Singapore, biology education from primary to pre-university has been organised as a continuum in the following manner:

a) From Primary 3 to 6, students learn about how life works at the systems level;
b) From Lower Secondary Science to Upper Secondary Biology, students learn about how life works through an understanding of the physiological processes in living organisms.
c) At the A-Level, students learn about how life works at the cellular and molecular level while understanding their implications on macro levels.

1.4 Aims

The Upper Secondary Biology syllabus seeks to develop in students the understanding, skills, ethics and attitudes relevant to the Practices of Science, enabling them to

a) appreciate practical applications of biology in the real world,
b) deepen their interest in biology for future learning and work,
c) become scientifically literate citizens who can innovate and seize opportunities in the 21st century, and
d) develop a way of thinking to understand how living organisms work to sustain life and use the disciplinary ideas in biology to approach, analyse and solve problems in biological systems.

The Disciplinary Ideas of Biology, the Practices of Science, and the Values, Ethics and Attitudes are elaborated in sections **1.5** to **1.7**.

1.5 Disciplinary Ideas of Biology

The disciplinary ideas of biology described below represent the overarching ideas which can be applied to explain, analyse and solve a variety of problems that seek to address the broader question of how living organisms work to sustain life. The purpose of equipping students with an understanding of these ideas is to develop in them a coherent view and conceptual framework of scientific knowledge to facilitate the application and transfer of learning. These ideas can be revisited throughout the syllabus, deepened at higher levels of learning and beyond the schooling years.

1. **The Cell** - Diverse life forms are similar in that their basic unit are cells.

2. **Structure and Function** - Structure and function of organisms from the molecular to the organ system levels are related to each other.

3. **Systems** - Biological systems interact among themselves and with the environment resulting in the flow of energy and nutrients.

4. **Energy** - To ensure survival, living organisms obtain, transform and utilise energy from the external world.

5. **Homeostasis, Co-ordination and Response** - Living organisms detect changes both from the surrounding environment and within themselves so that they are able to respond to these changes to maintain a constant internal environment needed for sustaining life.

6. **Heredity** - Genetic information is passed down from parents to offspring during reproduction to ensure the continuity of life.

7. **Evolution** - The diversity of living organisms is achieved through a process of evolution, driven by mechanisms such as natural selection.

1.6 Practices of Science

Teachers are encouraged to provide opportunities for students to develop the Practices of Science. It is important to appreciate that the three components of the Practices are intricately related.

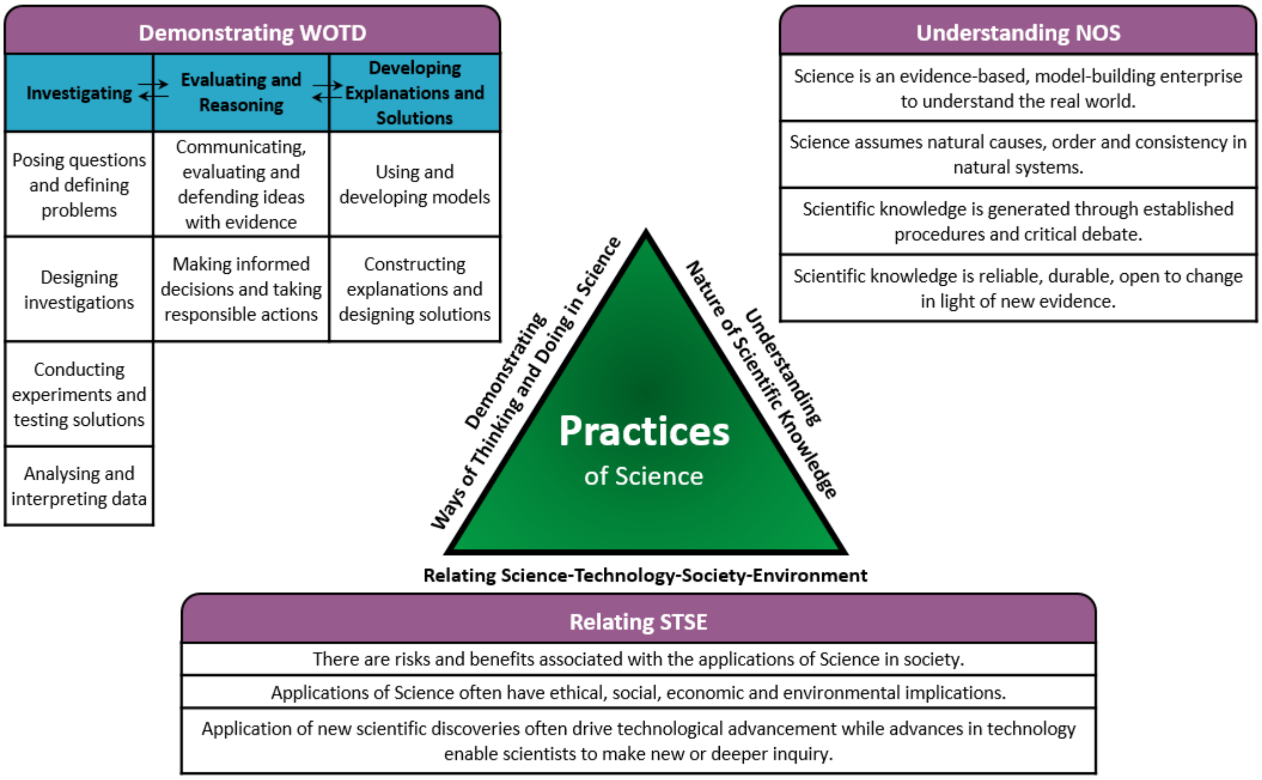

Figure 1.3: Practices of Science

1.7 Values, Ethics and Attitudes

Although science uses objective methods to arrive at evidence-based conclusions, it is in fact a human enterprise conducted in particular social contexts which involves consideration of values and ethics. The intent of fostering an awareness and appreciation of these values in the curriculum is to sensitise our students to the ethical implications of the application of science in society. The challenges that humanity will face in the upcoming centuries will not be overcome by scientific and technological solutions alone. There is a need to consider the impact of these solutions in terms of their benefits to humanity and the ethical issues involved. Thus, science education needs to equip students with the ability to articulate their ethical stance as they participate in discussions about socio-scientific issues[1] that involve ethical dilemmas, with no single right answers.

Values, Ethics and Attitudes	**Description**
Curiosity	Desiring to explore the environment and question what is found.
Creativity	Seeking innovative and relevant ways to solve problems.
Integrity	Handling and communicating data and information with complete honesty.
Objectivity	Seeking data and information to validate observations and explanations without bias.
Open-mindedness	Accepting all knowledge as tentative and suspending judgment. Tolerance for ambiguity. Willingness to change views if the evidence is convincing.
Resilience	Not giving up on the pursuit for answers / solutions. Willingness to take risks and embrace failure as part of the learning process.
Responsibility	Showing care and concern for living things and awareness of our responsibility for the quality of the environment.
Healthy Scepticism	Questioning the observations, methods, processes and data, as well as trying to review one’s own ideas.

[1] Examples of socio-scientific issues are genetic engineering (e.g. cloning and gene therapy), reproductive technology, climate change and the adoption of nuclear energy.

SECTION 2: CONTENT

Cells and the Chemistry of Life
The Human Body – Maintaining Life
Living Together – Plants and Animals

2. CONTENT

Content structure

The content of this syllabus is organised to reflect the hierarchical organisation of living organisms. This sequence allows students to systematically explore the functions and processes of living organisms at the various levels of life, with increasing complexity. It will also enable students to appreciate how the processes at different levels interact to carry out the activities necessary to maintain life.

Sections	Topics
Cells and the Chemistry of Life	1. Cell Structure and Organisation
	2. Movement of Substances
	3. Biological Molecules
The Human Body – Maintaining Life	4. Nutrition in Humans
	5. Transport in Humans
	6. Respiration in Humans
	7. Infectious Diseases in Humans
Living Together – Plants and Animals	8. Nutrition and Transport in Flowering Plants

Guide to using this section

This is a brief description of the features in **Sections 2.1-2.4.**

Section overview

2.1 Cells and the Chemistry of Life

Overview

Driving Question: What are living organisms made of at the cellular and molecular level?

Living things are different from non-living things in their ability to grow, reproduce, move, and respond to change. Understanding what makes these characteristics possible requires an appreciation of the hierarchical organisation of life (from cells → tissues → organs → systems → organism) and the processes needed to sustain life at each level.

In this section, we begin by exploring life at the smallest level. Amidst the great diversity of living organisms on earth, all living organisms are fundamentally similar at the smallest level; they are all made of cells and a common set of carbon-based molecules. Physiological processes in living organisms can be explained through activities happening at the cellular level. For instance, the transport of oxygen around the body is made possible by red blood cells that bind oxygen to haemoglobin

Driving question - sets the focus for each section.

Section narrative - highlights the value of learning the concepts covered in each section and the connections among the topics to guide teachers in making learning relevant and coherent.

Topic overview

TOPIC 1. CELL STRUCTURE AND ORGANISATION

- Plant and Animal Cells
- Cell Specialisation

Guiding Questions
- What is the basic unit of life?
- What are cells made of and how do they work?

Topic Description

Since the 17th century, scientists sought to find the basic unit of life as they believe it holds the key to explain what makes life possible. This search was accelerated by Antonie van Leeuwenhoek's invention of the microscope which extended our ability to see beyond the power of the human eye and led Robert Hooke to discover the cell as the basic unit of life. Technological advancements of microscopes over the years have allowed us to study the complex and intricately organised world within each cell with greater detail.

Just like workers in a factory, each organelle within each cell has a specific function to carry out. Such division of labour enables the organelles in a cell to work as a collective whole to carry out the vital processes needed to sustain life. Studying cell structure and its activities allows us to understand how living organisms work and through which, develop solutions to improve the quality of life (e.g. more effective medicines and crops with improved qualities).

Guiding Questions - highlight the essential takeaways for each topic.

Topic description - highlights the key ideas within each topic and the value of learning them to guide teachers in making learning relevant.

Learning Outcomes

Learning Outcomes
(a) identify and state the functions of the following cell structures (including organelles) of typical plant and animal cells from diagrams, light micrographs and as seen under the light microscope using prepared slides and fresh material treated with an appropriate temporary staining technique: • cell wall • cell membrane • cytoplasm • nucleus

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In order to sustain life, all living things require three macromolecules – carbohydrates, proteins and fats. They make life possible by providing energy, building cellular structures, and for growth and repair.

The overarching ideas of this section are cells as the basic unit of life, correlation between structure and function and how living organisms obtain, transform and utilise energy from the external world at the cellular level to sustain life. Knowing how life works at the cellular and molecular level will provide students with a foundation to understand processes needed to sustain life at the tissue, organ and system levels, which are covered in subsequent sections of this syllabus.

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(b) identify and state the functions of the following organelles from diagrams and electron micrographs: • mitochondria • ribosomes
(c) compare the structure of typical animal and plant cells
(d) explain how the structures of specialised cells are adapted to their functions (e.g. muscle cell – many mitochondria to supply more energy, root hair cell – large surface area of cell membrane for greater absorption, red blood cell – lack of nucleus allowing it to transport more oxygen)

TOPIC 2. MOVEMENT OF SUBSTANCES

- Diffusion
- Osmosis

Guiding Questions

- How do living organisms regulate the exchange of materials within themselves and with their environment?

Topic Description

Living organisms need to regulate the exchange of substances such as nutrients, water and waste products with the environment for survival. This exchange of materials relies on processes such as diffusion and osmosis to facilitate the movement of substances down a concentration gradient.

Empowering ourselves with knowledge of these transport processes have enabled us to come up with medical solutions to health problems such kidney dialysis, and invent innovative ways to solve water shortage problems through the innovation of NEWater.

Learning Outcomes
(a) define *diffusion* and describe its role in nutrient uptake and gaseous exchange in plants and humans
(b) define *osmosis,* investigate and describe the effects of osmosis on plant and animal tissues

TOPIC 3. BIOLOGICAL MOLECULES

- Carbohydrates, Fats and Proteins
- Enzymes

Guiding Questions

- What molecules do living organisms need to sustain life?
- Why do living organisms need enzymes and how do enzymes work?

Topic Description

Living organisms need to produce or obtain food that contains three main groups of nutrients which are carbohydrates, proteins and fats to sustain life. These nutrients usually come in the form of large molecules (macromolecules) and need to be broken down into smaller molecules and transformed in various ways to be used by living organisms. For example, large carbohydrate molecules need to be broken down into smaller molecules of glucose to be absorbed by body cells to release energy. The amount of nutrients required by different living organisms may vary, depending on their lifestyles and health statuses.

The breakdown of macromolecules is one of countless chemical reactions constantly happening in living organisms. Many of these chemical reactions are usually too slow and cannot sustain life. Hence, living organisms rely on an important group of proteins, known as enzymes, to alter or speed up the chemical reactions needed to drive many biological processes in living organisms such as digestion, photosynthesis and respiration. Without enzymes, life could slow to a crawl and may cease to exist. Understanding this unique characteristic of enzymes of being able to speed up biological processes has allowed industries to quicken the production of food and beverages, such as fruit juice.

Learning Outcomes
(a) state the main roles of carbohydrates, fats and proteins in living organisms: • carbohydrates as an immediate source of energy • fats for insulation and long-term storage of energy • proteins for growth and repair of cells
(b) describe and carry out tests for: • starch (using iodine in potassium iodide solution) • reducing sugars (using Benedict's solution) • protein (using biuret solution) • fats (using ethanol)
(c) state that large molecules are synthesised from smaller basic units: • cellulose, glycogen and starch from glucose • polypeptides and proteins from amino acids • lipids such as fats from glycerol and fatty acids
(d) explain the mode of action of enzymes in terms of an active site, enzyme-substrate complex and enzyme specificity using the 'lock and key' hypothesis
(e) investigate and explain the effects of temperature and pH on the rate of enzyme catalysed reactions

2.2 The Human Body – Maintaining Life

<u>Overview</u>

Driving question: How do human body systems work to maintain life?

Life is sustained through the integrated organisation of the whole organism. In humans, the maintenance and regulation of life processes include nutrition, transport and respiration. These processes are all part of different living systems, so how do they work?

Living systems utilise energy and macromolecules to maintain life processes such as growth, reproduction and homeostasis. Interactions also exist between living systems within organisms, which are often accompanied by the transfer of energy between matter and transfer or exchange of matter. Each system has their component parts, characterised by the division of labour. This division of labour enables an organism to function efficiently and allows for the various systems to work together as a co-ordinated whole.

The threat of diseases disrupts the maintenance of important life processes and the functioning of human body systems. In ancient times, the concept of 'catching' a disease was unheard of, and diseases were even thought to be caused by the imbalance of 'humours' (internal fluids) within the body. However, with the invention of the microscope, we have found out that infectious diseases are often caused by pathogens, e.g. viruses and bacteria.

The overarching ideas in the study of this section are the co-ordination of the human body system as a whole and the correlation between structure and function.

TOPIC 4. NUTRITION IN HUMANS

- Human Digestive System
- Physical and Chemical Digestion
- Absorption and Assimilation

Guiding Questions

- How does the human body obtain nutrients from food?
- How is blood glucose concentration regulated and how can we prevent and manage diabetes?

Topic Description

Humans need to eat to obtain nutrients and energy for growth, repair, and maintenance. The nutrients are released from the food we eat through the processes of digestion, absorption and assimilation. The structure of the alimentary canal is designed to carry out these processes efficiently. For instance, peristalsis of the muscular walls of the stomach helps to break large pieces of food into smaller pieces and mix them with the digestive juices for chemical digestion. The highly folded surface of the small intestine allows digested food to be more quickly absorbed into the bloodstream.

Accessory organs in our digestive system also play important roles in the digestion and assimilation of food. For instance, the liver produces bile, which is involved in fat digestion, and the pancreas produces digestive juices and hormones to regulate our blood glucose concentration.

Knowledge of the digestive system has enabled medical advancements in the design of oral medication. For instance, innovation of pills with different coatings ensures that medication is only released when the pills arrive at their target organs.

Learning Outcomes
(a) describe the functions of the various parts of the digestive system: mouth, salivary glands, oesophagus, stomach, duodenum, pancreas, gall bladder, liver, ileum, colon, rectum, anus, in relation to ingestion, digestion, absorption, assimilation and egestion of food, as appropriate
(b) describe the functions of enzymes (e.g. amylase, maltase, protease, lipase) in digestion, listing the substrates and end-products
(c) state the function of the hepatic portal vein as the transport of blood rich in absorbed nutrients from the small intestine to the liver
(d) state the role of the liver in: • conversion of glucose to glycogen and vice versa • fat digestion • metabolism of amino acids and formation of urea • breakdown of alcohol • breakdown of hormones
(e) define a *hormone* as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs
(f) outline how blood glucose concentration is regulated by insulin and glucagon
(g) describe type 2 *diabetes mellitus* in terms of a persistently higher than normal blood glucose concentration due to the body's resistance to insulin or insufficient production of insulin
(h) identify the risk factors of (e.g. unhealthy diet and sedentary lifestyle) and ways to manage type 2 *diabetes mellitus*

TOPIC 5. TRANSPORT IN HUMANS

- Parts and Functions of the Circulatory System
- Blood
- Coronary Heart Disease

Guiding Questions

- Why do humans need a circulatory system?
- What are the different parts and functions of the human circulatory system?
- How can we prevent coronary heart disease?

Topic Description

All living organisms need to exchange materials with their external environment for survival. This includes obtaining nutrients and oxygen needed to release energy and removal of waste products. Unlike unicellular organisms which simply exchange substances with their external environment through diffusion and osmosis, humans are complex multicellular organisms that need a circulatory system to do so. A healthy diet, exercising regularly and not smoking, is essential to maintain good cardiac health for our circulatory system to work efficiently.

The human circulatory system consists of a heart, blood vessels and blood as a transport medium. The structure of the heart and blood vessels are adapted to ensure the efficient exchange of substances within the body. For instance, the one-cell thick capillary wall allows the efficient exchange of substances between the blood and body cells. Apart from transport functions, the blood also plays important roles in defence against harmful substances such as bacterial infection. In Singapore, nearly 200 L of blood is required daily for use during medical emergencies and surgical procedures, and to treat patients with various life-threatening illnesses. The Singapore Red Cross helps to ensure that there is a steady supply of blood by organising blood donation drives and appealing for donors of specific blood groups when supply is low.

Learning Outcomes
(a) identify the main blood vessels to and from the heart, lungs, liver and kidney
(b) relate the structures of arteries, veins and capillaries to their functions (specific names of muscle layers in arteries and veins are **not** required)
(c) state the components of blood and their roles in transport and defence: • red blood cells – haemoglobin for oxygen transport • plasma – transport of blood cells, ions, soluble food substances, hormones, carbon dioxide, urea, vitamins, plasma proteins • white blood cells – phagocytosis, antibody formation and tissue rejection • platelets – fibrinogen to fibrin, causing clotting
(d) describe the structure and function of the heart in terms of muscular contraction and the working of valves (histology of the heart muscle, names of nerves and transmitter substances are **not** required)
(e) describe coronary heart disease in terms of the occlusion of coronary arteries and list the possible causes, such as unhealthy diet, sedentary lifestyle, and smoking, stating the possible preventative measures

TOPIC 6. RESPIRATION IN HUMANS

- Human Gas Exchange
- Cellular Respiration

Guiding Questions

- Why do humans need a respiratory system?
- What are the different parts and functions of the human respiratory system?
- Why is cellular respiration important and how does it work?
- What are the harmful effects of smoking?

Topic Description

In an earlier chapter, we learnt that humans obtain energy from the food we eat. Specifically, energy is locked in glucose molecules and can only be released when it reacts with oxygen in our body cells through a process known as cellular respiration. Hence, humans need a respiratory system to obtain oxygen from the air around us for cellular respiration to take place.

The human respiratory system contains a series of air passages, the lungs, the ribcage and diaphragm. These structures are adapted to facilitate the movement of air into and out of the body and efficient gas exchange within the lungs. For example, the one-cell thick wall of the alveoli ensures faster diffusion of gases between the lungs and the blood. The health of our respiratory system can be threatened by unhealthy habits such as smoking which decreases the respiratory system's efficiency in gaseous exchange.

Learning Outcomes
(a) identify the larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries and state their functions in human gaseous exchange
(b) explain how the structure of an alveolus is suited for its function of gaseous exchange
(c) state the major toxic components of tobacco smoke – nicotine, tar and carbon monoxide, and describe their effects on health
(d) define *aerobic respiration* in human cells as the release of energy by the breakdown of glucose in the presence of oxygen and state the word equation
(e) define *anaerobic respiration* in human cells as the release of energy by the breakdown of glucose in the absence of oxygen and state the word equation
(f) explain why cells respire anaerobically during vigorous exercise resulting in an oxygen debt that is removed by rapid, deep breathing after exercise

TOPIC 7. INFECTIOUS DISEASES IN HUMANS

- Organisms affecting Human Health
- Influenza and Pneumococcal Disease
- Prevention and Treatment of Infectious Diseases

Guiding Questions

- What causes diseases?
- How can diseases be prevented and managed?

Topic Description

Diseases, both infectious and non-infectious, threaten our health by disrupting the functions of human body systems. Previous topics have focused on non-infectious diseases, such as diabetes and heart diseases, their causes and preventive measures. This topic extends our understanding of diseases to infectious diseases in terms of their causes, prevention and treatment.

Infectious diseases are caused by pathogens such as bacteria and viruses which can spread between individuals. Important milestones in the prevention and cure of infectious diseases include Edward Jenner's discovery of a vaccine against the cowpox virus in 1796 and Alexander Fleming's hallmark discovery of the use of antibiotics to treat bacteria diseases in 1928. These discoveries saved millions of lives and changed the face of medicine. Unfortunately, the misuse and overuse of antibiotics led to the rapid rise of antibiotic-resistant bacteria, and we are now racing against time to develop new ways and drugs to fight such bacteria.

An increasingly interconnected world increases the spread of infectious diseases. An example close to home is the Coronavirus Disease 19 (COVID-19) outbreak. The virus was first discovered in 2019, and Singapore confirmed its first imported case in January 2020. Being highly infectious, it spread rapidly across the world and caused major disruptions to everyday life, involving closure of schools and businesses. To control its spread, the government put in several measures including emphasising good personal hygiene and restricting overseas travel.

Learning Outcomes
(a) state that infectious diseases can be spread from person to person whereas non-infectious diseases cannot and identify examples of each
(b) explain that infectious diseases are caused by pathogens such as bacteria and viruses and can be spread from person to person through body fluids, food and water (knowledge of the structure of bacteria and viruses is **not** required)
(c) state the signs and symptoms of: • influenza – caused by the influenza virus • pneumococcal disease – caused by the bacteria, pneumococcus
(d) describe the transmission and methods to reduce the transmission of: • influenza virus • pneumococcus
(e) state that vaccines contain an agent that resembles a pathogen and prevent infectious diseases by stimulating white blood cells to quickly produce antibodies when the pathogen invades
(f) state that antibiotics kill bacteria and are ineffective against viruses
(g) explain that the misuse and overuse of antibiotics may accelerate the emergence of antibiotic-resistant bacteria

2.3 Living Together – Plants and Animals

<u>Overview</u>

Driving Question: Why do living things need to interact with each other and how do they do so?

The sun is the principal source of energy for almost all living organisms on earth, without which, life will not exist as it is today. Green plants are able to capture and convert light energy to useful chemical forms through the unique process of photosynthesis.

Plants are important to most living organisms that depend on the energy captured by plants through direct or indirect feeding relationships to sustain life. The process of photosynthesis helps to capture the carbon dioxide released through respiration and other human activities such as combustion. This ensures that the concentration of carbon dioxide in the atmosphere is maintained within healthy limits, beyond which will result in global warming.

The overarching idea of this section is the adaptation of plant structures that allow them to transform light energy into chemical energy to sustain life on earth.

TOPIC 8. NUTRITION AND TRANSPORT IN FLOWERING PLANTS

- Plant Structure
- Photosynthesis
- Transpiration
- Translocation

Guiding Questions

- Why is photosynthesis important in maintaining life on earth?
- What happens during photosynthesis?
- How do plants obtain and transport the substances they need?

Topic Description

All life on earth ultimately depends on plants for food. Green plants are distinct from other life forms in their ability to capture light energy from the sun to make food. Ancient Greeks thought that plants get their food from soil. Jan Baptista van Helmont proved this idea wrong in 1649. He found that plants make food through a process known as photosynthesis and water is required for this process. Various scientists built on Helmont's discovery and found that water is not the only material needed for photosynthesis - light, carbon dioxide and chloroplasts are also required. Their collective discoveries can be summarised in the following equation:

$$\text{water + carbon dioxide} \xrightarrow[]{light,\ chlorophyll} \text{glucose + oxygen}$$

The structure of a plant and various environmental conditions affect its ability to obtain the raw materials needed for photosynthesis. Understanding the structure of plants and the process of photosynthesis allows us to engineer plants and design agricultural systems that can more efficiently harness energy from the sun to improve crop yield to feed an increasing world population.

Learning Outcomes
(a) identify the cellular and tissue structure of a dicotyledonous leaf, as seen in transverse section using the light microscope and describe the significance of these features in terms of their functions, such as the • distribution of chloroplasts for photosynthesis • stomata and mesophyll cells for gaseous exchange • vascular bundles for transport
(b) identify the positions of and state the functions of xylem vessels and phloem in sections of a herbaceous dicotyledonous leaf and stem, under the light microscope
(c) explain how the structure of a root hair cell is suited for its function of water and ion uptake
(d) state that chlorophyll absorbs light energy and converts it into chemical energy for the formation of carbohydrates and their subsequent uses
(e) briefly explain why most forms of life are completely dependent on photosynthesis
(f) state the word equation for photosynthesis (details of light-dependent and light-independent stages are **not** required)
(g) describe how carbon dioxide reaches mesophyll cells in a leaf
(h) investigate and describe the effects of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis (e.g. in submerged aquatic plants)
(i) state that *transpiration* is the loss of water vapour from the stomata
(j) briefly explain the movement of water through the stem in terms of transpiration pull
(k) investigate and explain: • the effects of variation of air movement, temperature, humidity and light intensity on transpiration rate • how wilting occurs
(l) define the term *translocation* as the transport of food (mainly sucrose) in the phloem tissue

SECTION 3: PEDAGOGY

Teaching and Learning of Upper Secondary Biology
Students as Inquirers
Blended Learning
Teachers as Facilitators
Practical Work
Use of ICT
Designing STEM Learning Experiences in Science

3. PEDAGOGY

3.1 Teaching and Learning of Upper Secondary Biology

We believe that all students are curious and want to explore and learn about things around them. The curriculum seeks to nurture students as inquirers by providing opportunities for them to explore and to appreciate the role of *Science for Life and Society*.

To nurture students as inquirers, teachers are key in facilitating a variety of learning experiences to support students in understanding *Core Ideas*, developing *Practices*, and cultivating *Values, Ethics and Attitudes*.

These learning experiences can be situated in various authentic contexts in both formal and informal settings and should inspire students to inquire and innovate. In designing purposeful and engaging learning experiences, teachers should consider amongst others, profile of students, resources available and relevant pedagogical approaches. Students should also be provided with opportunities to reflect on their own learning progress and act on feedback as part of Assessment for Learning (AfL).

Learning of science will not be complete without the incorporation of practical work, which develops in students the ways of thinking and doing while supporting their development of scientific knowledge and knowledge about science.

3.2 Students as Inquirers

For students to be inquirers, their thinking skills and dispositions should be developed as part of their learning experiences. To engage students as inquirers, they can be provided with learning experiences centred on authentic contexts that allow them to pose questions, be involved in discussions on socio-scientific issues, or be engaged in problem solving. Through these learning experiences, students are likely to

- ask questions as they engage with an event, phenomenon, problem or issue. They learn to be objective, ask questions which they are curious about and identify key variables of their questions. The questions and variables can guide the design of investigations, from which they draw valid conclusions.

- gather evidence to respond to their questions. They gather evidence through observations and collect qualitative or quantitative data using simple instruments. In the process, they have to make appropriate decisions about measurements or observations, which should be made with appropriate degree of precision and good details respectively.

- formulate explanations based on the evidence gathered. They explain their findings with integrity, based on evidence gathered (e.g. qualitative descriptions of observations or quantitative data collected over a time interval), conclusion(s) from the interpretation of experimental data or observations and underlying principles. They practise healthy scepticism towards the evidence gathered and observations made, and are aware of the effect of significant sources of errors on the reliability and validity of the explanations and conclusions reached.

- connect their explanations to various contexts. They explain how the concepts are related to or applied in various examples and contexts around them. This helps them to appreciate how science is relevant and universally applicable in everyday life and unfamiliar situations.

- communicate and justify their explanations. After data collection, they present and communicate the evidence in appropriate forms (e.g. tables, charts, graphs, with all quantitative data to an appropriate number of decimal places/significant figures) to facilitate the analysis of patterns and relationships. For example, they can use texts, drawings, charts, tables, graphs, equations or a combination of representations to support their explanations.

- reflect on their learning and progress. They can reflect on their learning (e.g. what they have learnt, how they would like to improve, what they are curious about) in different ways (e.g. ask questions, write journals). For laboratory-based learning experiences, students can propose how significant errors may be overcome or reduced, as appropriate, including how experimental procedures may be improved. These reflections help them take greater ownership of their own learning and develop deeper conceptual understanding.

3.3 Blended Learning

3.3.1 Why Blended Learning

Blended Learning in MOE's context transforms our students' educational experience by providing them with a more seamless blending of different modes of learning. The key intended student outcomes are to nurture (i) self-directed and independent learners; and (ii) passionate and intrinsically motivated learners.

An aspect of Blended Learning is the integration of home-based learning (HBL) as a regular feature of the schooling experience. HBL can be a valuable complement to in-person schooling. Regular HBL can equip students with stronger abilities, dispositions and habits for independent and lifelong learning, in line with MOE's Learn for Life movement.

Blended Learning presents an opportunity to re-think curriculum and assessment design and innovate pedagogies for a more effective and student-centric educational experience. It involves giving students more ownership and agency over how they learn, at a pace they are comfortable with. It also offers scope for teachers to tap the advantages of both in-person learning and distance learning to plan lessons best suited to each mode of learning opportunity.

3.3.2 What is Blended Learning

Blended Learning provides students with a broad range of learning experiences (see **Figure 3.1**).

Figure 3.1: Examples of Blended Learning experiences

Possible Blended Learning Experiences	What this means
Structured/Unstructured learning	A combination of structured time for students to learn within a given time frame and unstructured time for students to learn at their own pace and exercise self-management
Synchronous/Asynchronous learning	A combination of in-person schooling, live online lessons and online/offline learning where students learn remotely and at their own pace.
Within-curriculum/Out-of-curriculum learning	Opportunities for students to learn from and beyond the formal curriculum
Distance/In-person learning	Opportunities for students to learn during face-to-face lessons with teachers and peers in school, complemented by out-of-school learning activities
ICT-mediated/Non-ICT-mediated learning	Opportunities for students to learn through a combination of ICT-mediated and non-ICT-mediated learning experiences

Table 3.1: Elaboration of possible Blended Learning experiences

3.4 Teachers as Facilitators

In the teaching and learning process, teachers play an important role in stimulating students' curiosity, as well as encouraging students to see the value of science and its applications in their everyday lives.

To do these, teachers should ensure that the learning experiences provided for students go beyond learning facts and outcomes of scientific investigations. Teachers should play the role of facilitators to support students as inquirers.

As facilitators, teachers should:

- provide students with opportunities to ask questions about events/phenomenon/problems/issues that are related to their daily lives, society and environment;
- support students in gathering and using evidence;

- encourage students to formulate and communicate explanations based on evidences gathered;
- encourage students to apply concepts learnt in understanding daily events/phenomenon, finding solutions to problems/issues and creating products; and
- provide students with opportunities to reflect on their own learning progress and act on feedback provided through formative assessment.

The *Pedagogical Practices* in the *STP*, as shown in **Figure 3.2**, comprise four core *Teaching Processes* which lie at the heart of good teaching. Teachers can refer to the Teaching Processes and relevant Teaching Areas under each process to guide them in the design and enactment of students' learning experiences. To design student-centred learning experiences, teachers will need to consider student profiles, readiness and needs as they transit from lower to upper secondary, as well as understand the interest and aspirations of these students as they progress to the next stage of studies and the future workplace.

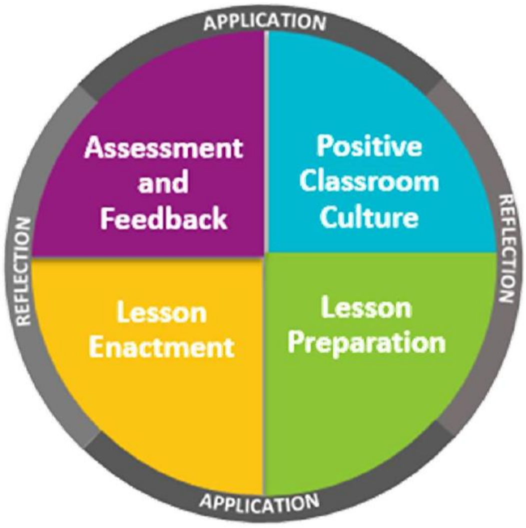

Figure 3.2: The four core *Teaching Processes* within the *Pedagogical Practices* in *STP*

3.5 Practical Work

Practical work is an essential component of science teaching and learning, both for the aim of developing students' scientific knowledge and that of developing students' knowledge about science.

Good quality science practical work supports the teaching and learning of science in the following ways:

- Develop science inquiry skills
- Develop experimental techniques and practical manipulative skills
- Understand the nature of scientific knowledge
- Enhance conceptual understanding
- Cultivate interest in science and in learning science

3.6 Use of ICT

Integrating ICT can enhance teaching and learning practices in the science classroom. Teachers are encouraged to harness:

- e-Pedagogy principles for lesson design;
- technology for active learning; and
- technology for assessment and feedback.

3.6.1 e-Pedagogy Principles for Lesson Design

<u>What is e-Pedagogy?</u>
e-Pedagogy is the practice of teaching with technology for active learning that creates a participatory, connected, and reflective classroom to nurture the future-ready learner.

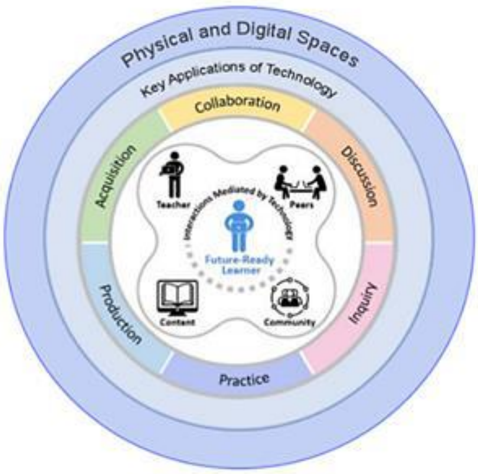

Figure 3.3: Overview of e-Pedagogy

Teachers can be guided by the Key Applications of Technology (see **Figure 3.3**) in designing different learning experience types to achieve the intended learning outcomes of the Science syllabus and the Science Curriculum Framework. The following are the LE types that teachers could design with technology: Acquisition, Collaboration, Discussion, Inquiry, Practice and Production. These learning experience types, occurring in the physical and/or digital spaces, capitalise on the role of technology in mediating learning interactions between the learner and the teacher, peers, content, and community.

3.6.2 Technology for Active Learning

Beyond the use of digital resources, there is a need to evaluate and select appropriate technological tools based on their pedagogical affordances and apply technologies to support active learning in science. For example, online collaboration tools can be used by teachers to facilitate students' co-construction of knowledge through scientific experimentation/investigations (inquiry-based learning) or discussion of science-related issues (socio-scientific issues-based learning).

In the Upper Secondary Biology syllabus, students can be acquainted with the use of basic digital tools (e.g. data loggers, mobile apps). Apart from better preparing students for the technologically driven world, using digital tools in the classroom also supports the development of the practices of science. For instance, when students are given opportunities to collect experimental data using these tools, competencies such as understanding experimental design, choosing appropriate probes or tools for data collection and data analysis can be developed. Digital tools can also enable students to visualise and explore biological systems and phenomena.

3.6.3 Technology for Assessment and Feedback

Meaningful integration of technology also supports teacher-student interactions. When students are given opportunities to demonstrate their understanding in multi-modal ways, supported by technology, rich learning data is available for assessment and feedback. In designing AfL items in the Singapore Student Learning Space (SLS), teachers should invite a range of different response strategies in order to assess students' learning, and use the monitoring features to understand students' learning gaps, provide timely feedback and track their learning progress.

3.7 Designing STEM Learning Experiences in Science

STEM education seeks to strengthen the interest and capabilities of our students in STEM to prepare them for an increasingly complex and uncertain world. We want our students to be curious about the world around them, to think creatively and critically in solving problems, and be concerned citizens who make a difference in society. These are in line with the goals of Science Education.

When designing STEM learning experiences, consider two aspects: 1) level of integration and 2) level of application. These two aspects lie on a continuum as illustrated in **Figure 3.4**.

Level of integration	***Disciplinary*** • Learning is anchored within a discipline.	⟷	***Integrative*** • Learning involves integration of concepts/skills across two or more STEM disciplines.
Level of application	***Learning knowledge and skills through real-world examples*** • Use of real-world examples to illustrate concepts. • Involves application of knowledge/skills to solve simplified/routine problems set in real-world contexts.	⟷	***Creative application of knowledge and skills in real-world contexts*** • Creative application of knowledge and skills (e.g. in ideating and making) to address real-world issues. • Involves application of knowledge/skills to solve complex real-world problems.

Figure 3.4 Design considerations for STEM Learning

SECTION 4: ASSESSMENT

4. ASSESSMENT

4.1 Purposes of Assessment

Assessment is the process of gathering and analysing evidence about student learning to make appropriate decisions and enhance learning. Assessment is integral to the teaching and learning process. In designing assessments, we need to have **clarity of purpose**. Assessment measures the extent to which desired knowledge, skills and attitudes are attained by students. It should produce both quantitative and qualitative descriptions of a learner's progress and development that can be analysed and used to provide feedback for improving future practices.

- Assessment provides feedback to **students**. It allows them to understand their strengths and weaknesses. Through assessment, students can monitor their own performance and progress. It also points them in the direction they should go to improve further. The use of feedback in this way helps students work towards mastering their 21CC.

- Assessment provides feedback to **teachers**. It enables them to understand the strengths and weaknesses of their students. It provides information about students' attainment of learning outcomes (which includes 21CC development) as well as the effectiveness of their teaching.

- Assessment provides feedback to **schools**. The information gathered facilitates the placement of students in the appropriate course, and the promotion of students from one level to the next. It can also help to inform the review of the instructional programmes in schools.

- Assessment provides feedback to **parents**. It allows them to monitor their children's learning attainment and progress through the information obtained.

4.2 Scope of Assessment

Besides knowing the reasons for assessment, it is important to be clear about what is being assessed. If the assessment objectives are not clear, then the information obtained from the assessment process will not help improve student learning; neither will the information be meaningful for making decisions about student progression.

The *Science Curriculum Framework* shares that students should be provided with strong grounding in the three fundamentals:

- Core Ideas of Science
- Practices of Science
- Values, Ethics and Attitudes (VEA) in Science

These broad goals are translated into more specific learning objectives under the Subject Content section.

While VEA are usually not assessed formally, informal assessment is encouraged.

4.3 Designing Assessment for Learning (AfL)

Assessment for Learning (AfL) is assessment conducted constantly during classroom instruction to support teaching and learning. The critical feature about AfL is that information gathered from the assessment is used to adjust and improve the teacher's teaching strategies, as well as surface students' learning progress and difficulties.

4.4 Designing Assessment of Learning (AoL)

Assessment of Learning (AoL) aims to summarise how much or how well students have achieved at the end of a course of study over an extended period of time. The Preliminary and O/N-Level examinations are examples of AoL. To ensure content validity, the assessment should be designed to cover a representative sample of the syllabus. The assessment content should reflect the scope of the syllabus and be pitched at the appropriate demand.

For more information on the scheme of assessment for the national examinations, please refer to the Singapore Examinations and Assessment Board.

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