SCIENCE
SYLLABUS
Upper Secondary
Normal (Technical) Course

Implementation starting with
2023 Secondary Three Cohort

Ministry of Education
SINGAPORE

TABLE OF CONTENTS

SECTION 1: INTRODUCTION

Science Curriculum Framework
Developing 21st Century Competencies through Science
Aims of Upper Secondary Science Normal (Technical) Syllabus
Core Ideas of Science
Practices of Science
Values, Ethics and Attitudes

1. INTRODUCTION

1.1 Science Curriculum Framework

The *Science Curriculum Framework* (see **Figure 1**) encapsulates the thrust of Science education in Singapore to provide students with strong fundamentals in Science for life, learning, citizenry and work.

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

Figure 1: Science Curriculum Framework

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

- To enthuse and nurture all students to be scientifically literate, so that they are able to make informed decisions and take responsible actions in their daily lives; and

- To provide strong Science fundamentals for students to innovate and pursue STEM for future learning and work.

Surrounding the core of the framework are the 3 **In**s, *Inspire*, *Inquire* and *Innovate,* which articulates 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. Students are open to the possibility of pursuing Science-related careers to serve the good of society.

- Inquire like scientists. Students have strong fundamentals in science, and possess the spirit of scientific inquiry. They are able to engage confidently in the *Practices of Science*, 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 science to generate creative solutions to solve real-world problems, ranging from those affecting everyday lives to complex problems affecting humanity. It is envisaged that there will be a strong pipeline of students who 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 (CI) of Science. To make science learning coherent and meaningful, the Science curriculum is organised around *Core Ideas*, which are the distilled ideas central to Science. The *Core Ideas* help students see the coherence and conceptual links *within* and *across* the different sub-disciplines of science (i.e., biology, chemistry and physics).

- Practices of Science (POS). The *Practices of Science* 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 processes 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 of Science* 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 of Science* 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. 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 that involve ethical dilemmas, with no single right answer.

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 Developing 21st Century Competencies through Science

To prepare our students for the future, a Framework for 21st Century Competencies (21CC) and Student Outcomes was developed by MOE (see **Figure 2**). This 21CC framework guides the purposive development, through the total curriculum, of key competencies and mindsets for students to thrive and contribute in the 21st century.

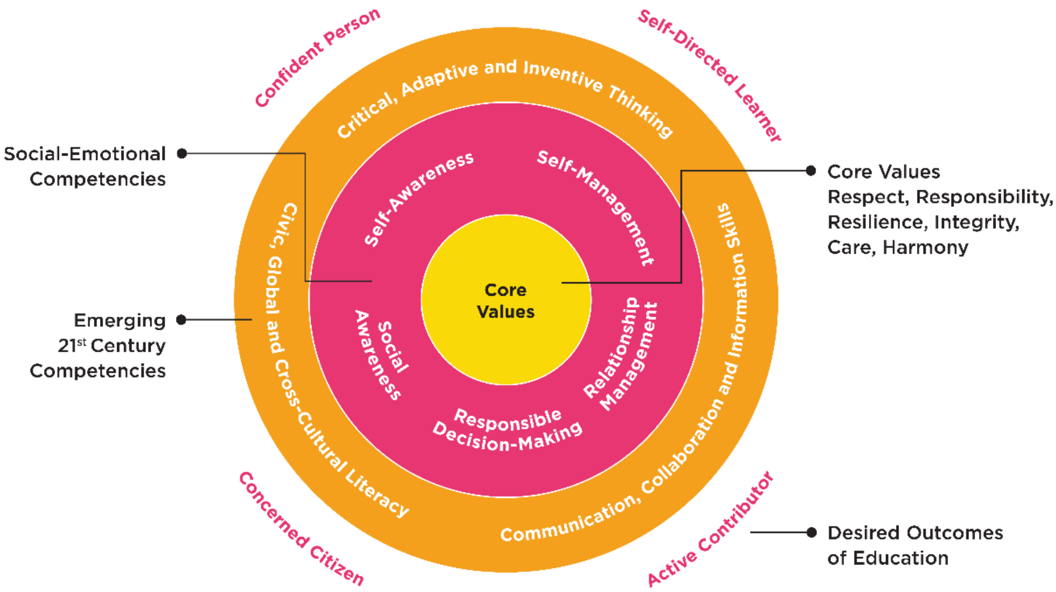


Figure 2: Framework for 21st Century Competencies and Student Outcomes

In Singapore, science education plays a crucial role in equipping our students to understand and tackle the myriad of local and global challenges of the 21st century. These challenges include issues such as climate change, technological disruptions (e.g. artificial intelligence), and the sustainable management of resources to support urban development and economic growth. To effectively address these challenges, it is vital to cultivate scientifically literate citizens who:

- Possess the mindset and practical knowledge of science and its applications to make informed decisions and take responsible actions in their daily lives.
- Appreciate science as part of humanity's intellectual and cultural heritage, recognising the beauty and power of its ideas, and engaging in socio-scientific issues ethically and in an informed manner.
- Can apply scientific knowledge and skills, as well as embrace scientific attitudes and mindsets to innovate and explore new frontiers.

In this respect, engaging our students in the Practices of Science (POS) is aligned with the larger goal of developing 21CC in our students. The emerging 21CC that can be most naturally developed through science are **Critical Thinking**, **Inventive Thinking** and **Communication**, while the development of the others depends on the context of the lesson. Intentional development of 21CC through science makes learning meaningful and facilitates the transfer of learning (refer to **Table 1** for specific examples).

Table 1 Examples of 21CC development in science

<table>
<tr><td colspan="2">Critical Thinking

Critical Thinking refers to the ability to exercise sound reasoning and metacognitive thinking to interpret and analyse information and evidence, draw conclusions, make decisions, and solve problems.</td></tr>
<tr><th>Developmental Milestone</th><th>Example of how it could look like in a secondary science classroom</th></tr>
<tr><td>• Use evidence and adopt different viewpoints to explain their reasoning and decisions, having considered the implications of the relationship among different viewpoints.
• Plan, organise and evaluate their thinking strategies to monitor their learning. Suspend judgement, reassess conclusions and consider alternatives to refine their thoughts, attitudes, behaviour and actions.</td><td>Students could be given opportunities to:
• draw conclusion(s) from the interpretation of observations and/or experimental data and underlying principles.
• compare and assess competing claims in the context of currently accepted explanations, limitations (e.g., trade-offs), constraints, and ethical issues.
• identify and analyse a situation, reflecting on the implications of decisions (e.g., weighing risks and benefits) by appreciating and evaluating diverse viewpoints, including scientific/technological, economic, social, environmental, and ethical considerations, using evidence to support their viewpoints.</td></tr>
<tr><td colspan="2">Inventive Thinking

Inventive Thinking refers to the ability to frame, investigate and explore issues, generate innovative ideas and evaluate them to form novel and useful responses.</td></tr>
<tr><th>Developmental Milestone</th><th>Example of how it could look like in a secondary science classroom</th></tr>
<tr><td>• Generate ideas that are unique or modified substantially from existing ones and explore different pathways that lead to solutions.
• Evaluate and refine their ideas iteratively, using relevant strategies and based on a set of criteria that is appropriate for the task or context.</td><td>Students should be given opportunities to
• design investigations to inquire into specific phenomena or solve issues set in authentic contexts, with consideration for relevance and accuracy.
• evaluate and refine ideas and solutions in a systematic and iterative manner through applying logic, collection of evidence, experimentation, and applying scientific knowledge.
• ensure that their ideas and solutions developed through experimentation are appropriate for the context in which they are developed.</td></tr>
</table>

Communication **Effective communication** refers to the ability to convey information and exchange ideas clearly and coherently through multimodal ways for specific purposes, audiences and contexts.	
Developmental Milestone	**Examples of how it could look like in a secondary science classroom**
• Convey and critically evaluate knowledge to co-construct new understandings and complex ideas persuasively and with impact, while considering the specific purpose and context of communication. • Respond with respect and empathy. The student is sensitive to the diverse backgrounds that influence the context of communication with others.	Students should be given opportunities to • communicate and evaluate scientific findings and information using various modes of communication (e.g., written, verbal, pictorial, tabular, or graphical) while employing scientific concepts and ideas. • seek feedback and/or acceptance of explanations or solutions within the class or wider community.

1.3 Aims of Upper Secondary Science Normal (Technical) Syllabus

The aims of the Upper Secondary Science Normal (Technical) Syllabus are to

(i) develop 21st century competencies in students which would enable them to
- apply critical and inventive thinking to identify and solve problems;
- communicate and collaborate with others effectively; and
- show care and concern for people and the environment.

(ii) guide students in acquiring knowledge, skills and values for application in their daily lives such that they
- are motivated to learn science through contextualised and hands-on learning;
- become confident citizens who are able to make sound decisions tapping on science and technology;
- develop safe and ethical practices; and
- understand the use of ICT and appropriate tools for scientific inquiry and analysis of issues.

(iii) prepare students for future learning and work such that they
- become lifelong and motivated learners; and
- develop skills which are useful and relevant for them to be contributing citizens.

1.4 Core Ideas of Science

Core Ideas allow students to appreciate the interconnections of scientific concepts across topics, making science more meaningful for students.

For each topic in the syllabus, key *Core Ideas* are suggested. In the teaching and learning of the syllabus, teachers are encouraged to draw links to other *Core Ideas* besides the suggested ones. The suggestion of the key *Core Ideas* for each topic is not meant to be exhaustive. In the syllabus, students would have the opportunity to appreciate the following eight *Core Ideas* (see **Table 2**).

Table 2: Core Ideas of Science

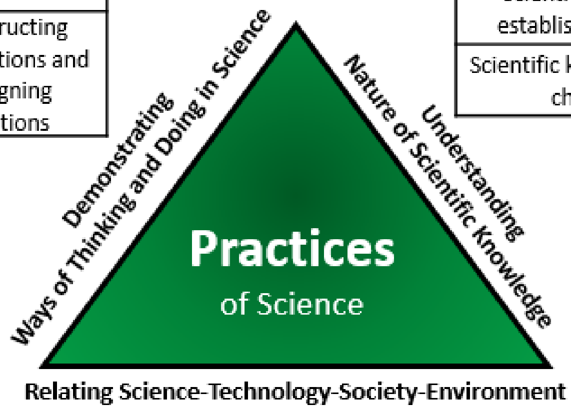
Core Idea	Description
Pattern	A pattern is an observed sequence or repetition in nature. A way to make sense of the world around us is to organise its diversity through classification based on similarities and differences, and recognising deviations. Understanding patterns helps us to predict events and processes that occur in the natural world.
Diversity	Diversity refers to the variety of living and non-living things around us. Such diversity in the natural and man-made worlds helps to maintain a balance in the ecosystem and provides us with useful resources to develop solutions to real-world problems. We have to use the resources in nature responsibly and sustainably.
System	A system comprises parts which interact with one another within a boundary. Interactions within and between systems can be explored at different scales. Studying systems allows us to understand how different parts with different functions, may work together for a common purpose.
Structure	Structure refers to the arrangement of and relations between parts of a system. Making sense of the structure of systems and their parts leads to a deeper understanding of their functions and properties, which allows us to make and test predictions of their behaviours.
Energy	Energy is required for things to work. The total amount of energy within a chosen system is always the same (i.e., conserved). While energy cannot be created or destroyed, it can be transferred from one energy store to another during an event or process. In these processes, some energy may become less useful.
Matter	Matter is anything that has mass and occupies space. Matter in the Universe, living and non-living, is made up of very small particles called atoms. The behaviour and arrangement of the atoms explain the properties of different materials. We can better appreciate nature by understanding the structure and properties of matter.
Balance	Balance is achieved when opposing forces or influences act on a system to allow the system to be in equilibrium or in a steady state. Maintaining balance is important in living things and in ecosystems. We are able to design stable systems by understanding the mechanisms by which balance is achieved.
Change	Change is caused by interactions within and across systems, which may involve forces or the flow of matter and energy. Different types of interactions allow us to understand the behaviour of systems and make predictions on how changes in one factor affects the other factors in a system.

1.5 Practices of Science

Teachers are encouraged to provide opportunities (e.g., hands-on activities, case studies) for students to develop *Practices of Science* (see **Figure 3**). It is important to appreciate that the three components of the *Practices of Science* are related.

Demonstrating WOTD		
Investigating ⇄	**Evaluating and Reasoning** ⇄	**Developing Explanations and Solutions**
Posing questions and defining problems	Communicating, evaluating and defending ideas with evidence	Using and developing models
Designing investigations	Making informed decisions and taking responsible actions	Constructing explanations and designing solutions
Conducting experiments and testing solutions		
Analysing and interpreting data		

Understanding NOS
Science is an evidence-based, model-building enterprise to understand the real world.
Science assumes natural causes, order and consistency in natural systems.
Scientific knowledge is generated through established procedures and critical debate.
Scientific knowledge is reliable, durable, open to change in light of new evidence.



Relating STSE
There are risks and benefits associated with the applications of Science in society.
Applications of Science often have ethical, social, economic and environmental implications.
Application of new scientific discoveries often drive technological advancement while advances in technology enable scientists to make new or deeper inquiry.

Figure 3: Practices of Science

In the N(T) Science classroom, students should be actively engaged in hands-on activities and ‘making’ projects which require them to work on real-world problems.

Details on each component of the *Practices of Science* is provided below. In **Section 2.3**, a list of learning experiences is provided for each module. Teachers are encouraged to conduct the learning experiences to develop *Practices of Science* in students, bearing in mind the specific purpose of each lesson and not attempting to achieve too many diverse objectives in a lesson.

A. Demonstrating Ways of Thinking and Doing

The component on *Ways of Thinking and Doing* in science illustrates the set of established procedures and practices associated with scientific inquiry to gather evidence and test ideas on how the natural world works. There are three broad, iterative domains of scientific activity: (i) investigating, (ii) evaluating and reasoning, and (iii) developing explanations and solutions.

(i) Investigating

W1. **Posing Questions and Defining Problems**. Scientific questions initiate the drive to find out more about the natural and man-made world(s), such as what is and how it works. The applications of science are motivated by finding solutions to problems. This also involves asking questions and scoping the problem so that it may be solved through the application of science and technology.

W2. **Designing Investigations**. Scientific investigations are often carried out as part of scientific inquiry into a phenomenon or testing of a theory or model that explains the world. In the applications of science, investigations are also carried out to identify the most appropriate solution or determine how to improve on a technological system. Various criteria (e.g., fairness) are considered in planning investigations, including the general approach, the apparatus and equipment needed and type of data (qualitative/ quantitative) needed.

W3. **Conducting Experiments and Testing Solutions**. This involves the application of techniques, methods and understanding on a range of apparatus and equipment and/ or apply methods.

W4. **Analysing and Interpreting Data**. Scientists are actively involved in organising and interpreting data to reveal any patterns and relationships that may serve as evidence for communicating to others. In the applications of science, engineers make use of these evidence to decide on and/or predict the efficacy of a model or prototype.

(ii) Evaluating and reasoning

W5. **Communicating, Evaluating and Defending Ideas with Evidence**. *Practices in Science* and technology involve clear and persuasive communication of ideas in various forms (e.g., oral, written, visual) and media (e.g., journal, newspaper, news). In the process, reasoning, argumentation and critique of ideas are practised, based on evidence, such that explanations and designed solutions become acceptable within the scientific and technological communities.

W6. **Making Informed Decisions and Taking Responsible Actions**. This involves identifying, analysing a situation competently and reflecting upon the implication of decisions made based on various considerations (e.g., economic, social, environmental and ethical).

(iii) Developing explanations and solutions

W7. **Using and Developing Models**. Models are approximations of phenomena or systems that are based on evidence and hold potential for describing, explaining and predicting phenomena to aid scientific inquiry and/or analyse technological systems. Models may be revised if new evidence reveals existing limitations.

W8. **Constructing Explanations and Designing Solutions**. Science strives to explain the causes of phenomena while scientific applications endeavour to solve problems. The process of constructive explanations and designing solutions are iterative and systematic.

B. Understanding the Nature of Scientific Knowledge

N1. **Science is an evidence-based, model-building enterprise concerned with understanding the natural world**. Science is a unique way of knowing which uses empirical standards, logical arguments, and sceptical reviews. It consists both a body of knowledge of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge.

N2. **Science assumes there are natural causes for physical phenomena and an order and consistency in natural systems**. Scientists often use hypotheses to develop and test theories and explanations. They use models, mechanisms, and explanations as tools to develop scientific theories. Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Laws are regularities or descriptions of natural phenomena. A scientific theory is a substantiated explanation of an aspect of the natural world, based on a body of facts that has been repeatedly verified through observation and experimentation. Theories are validated by the scientific community before they are accepted.

N3. **Scientific knowledge is generated using a set of established procedures and practices, and through a process of critical debate within the scientific community**. Collaboration by students in their science learning echoes the social nature of science for practising scientists. Just as professional scientists, students should present their work and ideas to others as part of the scientific community. Creativity is essential in science as with other ways of knowing. Students can be creative in science as they develop multiple ways to observe and measure, when they propose inferences and suggest predictions, and when they stretch to develop more than one explanation for data.

N4. **Scientific knowledge is reliable and durable, yet open to change in the light of new evidence**. Scientific explanations are tentative and open to revision if sufficient evidence or arguments can be provided. Scientific knowledge advances as old ideas are replaced by better explanations.

C. Relating Science-Technology-Society-Environment

R1. There are risks and benefits associated with the applications of science in society. Science and its applications have the potential to bring about both benefits and harm to society.

R2. Applications of science often have ethical, social, economic, and environmental implications.

R3. Applications of new scientific discoveries often inspire technological advancements while advances in technology motivate scientists to ask new questions and/ or empower scientists in their inquiry (e.g., collecting more precise data or carrying out more complex data analysis).

1.6 Values, Ethics and Attitudes

In learning science, the adoption of certain values, ethics and attitudes such as curiosity, creativity, integrity, objectivity, open-mindedness, resilience, responsibility and healthy scepticism is advocated. The use of authentic and familiar contexts in the syllabus allows students to have discussions on social and ethical issues grounded in scientific knowledge.

Table 3 gives a description of each of the value, ethic and attitude.

Table 3: Values, Ethics and Attitudes in Science

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.

SECTION 2: CONTENT

Syllabus Framework
Guide to the Syllabus
Syllabus Content

2. CONTENT

2.1 Syllabus Framework

Our fraternity believes that every child wants to and can learn. When children find meaning in learning, they are motivated to take ownership of their own learning. Based on this set of beliefs, the Upper Secondary Science Normal (Technical) syllabus comprises three modules, namely *Machines Around Us (II)*, *Food Matters*, and *Our Body and Health (II)*, that are situated in authentic contexts students can relate to. The contexts draw students into asking questions and seeking knowledge that can help them gain a deeper understanding of the content in each module. For example, from the module *Food Matters*, students will wonder how food is produced and processed to make it suitable for eating. This would encourage students to engage in self-directed learning where they find out more about the methods used to make food safe to eat.

The content in each of the modules is anchored on key inquiry questions. These questions provide an overarching frame to guide instruction and learning of the content. Teachers could use the key inquiry questions as a starting base to delve further into a series of related questions, to facilitate students' understanding of the interconnections of the scientific concepts. **Table 4** provides the key inquiry questions of each module.

Table 4: Key inquiry questions for all modules

Module	**Key Inquiry Question**
Machines Around Us (II)	How do we use energy conversions to make our lives better? How is electricity generated and transmitted? How do we use electrical circuits to make our lives better? How do we use waves to make our lives better? How do we use effects of force to make our lives better?
Food Matters	How do we produce enough food for the population? How do we use separation techniques and chemical reactions to make our lives better? How do we ensure that our food is safe to eat?
Our Body and Health (II)	How do we stay healthy? How does our digestive system keep us alive? How does our respiratory system keep us alive? How does our circulatory system keep us alive?

Table 5 provides an overview of the syllabus content. There is no particular order in which the modules should be taught. The teaching and learning of the topics within a module should be viewed as interlinked and not as compartmentalised blocks of knowledge.

Table 5: Overview of syllabus content

Module	**Machines Around Us (II)**	**Food Matters**	**Our Body and Health (II)**
Topic	• Energy • Electricity • Wave • Effects of Force	• Sources of Food • Food Chemistry • Food Safety	• Staying Healthy • Digestion • Breathing • Blood Circulation

2.2 Guide to the Syllabus

This section provides brief descriptions of the features in **Section 2.3**.

<u>Module Overview</u>

Module 4

MACHINES AROUND US (II)

Overview

Machines around us help to improve our quality of life. For example, a portable fan keeps us cool in our hot weather. When machines are in use, energy conversions usually occur. For example, chemical potential energy of the battery in the portable fan is converted to kinetic energy of the blades and sound energy when the fan is in operation.

Many machines operate using electricity. In Singapore, most electricity is generated at power stations and is transmitted to these machines through a grid of underground transmission lines. These machines have combinations of circuit components in different arrangements that are designed to convert electrical energy to useful forms of energy. For example, a mobile phone has circuits that give off light and sound, which are types of waves, when we play a video.

Machines usually experience effects of forces during operation. When a cyclist steps on the pedals, the bicycle wheels experience turning effect and the bicycle accelerates from rest.

Key Inquiry Questions

- How do we use energy conversions to make our lives better?
- How is electricity generated and transmitted?
- How do we use electrical circuits to make our lives better?
- How do we use waves to make our lives better?
- How do we use effects of force to make our lives better?

Overview
Describes the "why" behind studying the module. The narrative facilitates students' appreciation of why studying the module is relevant and important, and how through the learning, students will be able to make informed decisions and take responsible actions in their daily lives. It also highlights the interconnections between the topics in the module.

Key Inquiry Questions
Frame the study of the context and key concepts covered in the module. The use of these questions serves to facilitate the inquiry process in the teaching and learning of the topics in the module. It allows students to be inspired and to inquire about Science in their daily lives.

Topic Overview

4. EFFECTS OF FORCE

Topic Description
Highlights some key concepts and suggested *Core Idea(s)*.

Topic Description
A force is a push or pull. Although forces cannot be seen, many of their effects are observed in our daily lives.

A force can ***change*** the motion of an object, which can be described in terms of its speed and acceleration. The motion of the object can also be represented on a distance-time graph. For example, the weight of an apple (a force) causes it to break off a tree and accelerate as it falls to the ground. In other words, the speed of the apple and the distance travelled by the apple per unit time increase with time.

A force can also bring about turning effect of an object. For example, applying a force on a doorknob may cause the door to turn on its hinges.

Content
- Effects of force
- Speed and acceleration
- Distance-time graph

Key Inquiry Question
- How do we use effects of force to make our lives better?

Suggested Core Idea
- Change

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values, Ethics and Attitudes*	Suggested Learning Experiences
(a) use a ruler and a measuring tape to measure length (b) use a digital stopwatch to measure time interval (c) show an understanding of the following effects of force: (i) change in shape and/or size of an object (ii) change the state of rest or motion of an object (including change in speed and/or direction) (iii) bring about turning effect of an object (d) show an understanding of what is meant by speed and acceleration (e) recall and apply the relationship *average speed = total distance / total time taken* to solve problems (f) recall and apply the relationship *acceleration = change in speed / time taken* to solve problems (for motion in one direction only) (g) plot and interpret a distance-time graph (h) describe the moment of a force in terms of its turning effect and relate this to everyday examples (knowledge of equations is **not** required) (i) appreciate science for its usefulness in improving quality of life: knowledge of effects of force helps us understand how machines work	• **Topic 4 Guide** • 4.1A Developing Your Understanding • 4.2A Measuring Length • 4.2B Making a Water Clock • 4.2C Finding the Speed of a Moving Marble • 4.2D Developing Your Understanding • 4.2E Distance-Time Graphs • 4.2F Using Force to Change the State of Rest of Motion of an Object • 4.2G Developing Your Understanding • 4.3A Moments in Our Daily Lives • 4.3B Developing Your Understanding • Mastering Your Learning

Suggested Learning Experiences
Lists learning experiences in the Activity Book and SLS that
- enhance understanding of concepts and *Core Ideas*;
- develop *Practices of Science*; and
- cultivate *Values, Ethics and Attitudes*.

2.3 Syllabus Content

Module 4
MACHINES AROUND US (II)

Overview

Machines around us help to improve our quality of life. For example, a portable fan keeps us cool in our hot weather. When machines are in use, energy conversions usually occur. For example, chemical potential energy of the battery in the portable fan is converted to kinetic energy of the blades and sound energy when the fan is in operation.

Many machines operate using electricity. In Singapore, most electricity is generated at power stations and is transmitted to these machines through a grid of underground transmission lines. These machines have combinations of circuit components in different arrangements that are designed to convert electrical energy to useful forms of energy. For example, a mobile phone has circuits that give off light and sound, which are types of waves, when we play a video.

Machines usually experience effects of forces during operation. When a cyclist steps on the pedals, the bicycle wheels experience turning effect and the bicycle accelerates from rest.

Key Inquiry Questions

- How do we use energy conversions to make our lives better?
- How is electricity generated and transmitted?
- How do we use electrical circuits to make our lives better?
- How do we use waves to make our lives better?
- How do we use effects of force to make our lives better?

1. ENERGY

Topic Description

Energy is the ability to do work and takes on different forms. When machines are in use, based on the principle of conservation of energy, the energy of their ***systems*** is not created or destroyed but is ***changed*** from one form to another and/ or transferred from one region to another. For example, a bus converts chemical potential energy of diesel to kinetic, thermal and sound energy. With a more powerful engine, the chemical potential energy can be converted to kinetic energy at a faster rate, enabling the bus to have a greater acceleration.

Many machines are designed to convert electrical energy to other forms of energy to make our lives better. Electrical energy is usually generated in fossil fuel power stations and transmitted to our machines through a grid of transmission lines. With the help of transformers, electricity can be transmitted at high voltages to reduce energy loss. Transformers also enable our machines (e.g., electrical appliances) to use electricity at their operating voltages.

Content

- Energy conversion and conservation
- Power
- Electricity generation and transmission

Key Inquiry Questions

- How do we use energy conversions to make our lives better?
- How is electricity generated and transmitted?

Suggested *Core Ideas*

- Change
- Energy
- System

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values, Ethics and Attitudes*	Suggested Learning Experiences
(a) show an understanding that electrical energy, kinetic energy, light energy, potential energy (chemical, elastic and gravitational), sound energy and thermal energy are examples of different forms of energy (b) show an understanding that thermal energy is transferred from a region of higher temperature to a region of lower temperature until both regions reach the same temperature (c) state the principle of conservation of energy and apply the principle to solve problems (d) recall and apply the relationship *power* = *energy* / *time taken* to solve problems (e) describe the generation of electricity with reference to the energy conversions that take place in fossil fuel power stations (f) explain why electricity is transmitted from power stations through a grid of high voltage transmission lines	• **Topic 1 Guide** • 1.1A Energy Around Us • 1.1B Seeing is Believing • 1.1C Swinging Bottle • 1.1D Developing Your Understanding • 1.2A Making My Own Water Heater [Teacher Demonstration] • 1.2B Developing Your Understanding • 1.3A Generating Electricity • 1.3B The Energy Trilemma • 1.3C Developing Your Understanding

(g) describe the use of step-up and step-down transformers in transmission of electricity and in electrical appliances (the term *alternating current* is **not** required) (h) appreciate science for its usefulness in improving quality of life: knowledge of energy helps us understand how machines work	• Mastering Your Learning

2. ELECTRICITY

Topic Description

Electrical systems contain combinations of electrical components connected in different ***structures*** (e.g., in series or parallel). The arrangement of electrical components not only affects the effective resistance of a circuit but also the current through and voltage across each component in a certain ***pattern***. There are advantages to connecting electrical components and machines in certain structures. For example, lamps in our homes are connected in parallel so that other lamps are not affected when one lamp blows.

Electricity is an important way of transferring ***energy*** as many machines (e.g., electrical appliances) tap on it to perform actions to make our lives better. These machines usually have labels that indicate their power ratings, which can be used to determine their electricity usage and the cost of electricity to use them. This information can help us to make informed decisions about our electricity usage to reduce electrical energy wastage.

Content

- Series and parallel circuits
- Electric power and energy

Key Inquiry Question

- How do we use electrical circuits to make our lives better?

Suggested *Core Ideas*

- Energy
- Pattern
- Structure

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values, Ethics and Attitudes*	**Suggested Learning Experiences**
(a) draw and interpret circuit diagrams, and set up circuits, with power sources (cell or battery), switches, lamps, resistors (fixed and variable), bells, fuses, ammeters and voltmeters (b) identify series and parallel arrangements of circuit components (c) use a multimeter to measure current, voltage and resistance (d) state that the current is the same at every point in a series circuit (e) state that the current through the power source is the sum of the currents in the separate branches of a parallel circuit (f) state that the voltage across the power source is equal to the sum of voltages across the other components in a series circuit (g) state that the voltage is the same across the separate branches of a parallel circuit (h) state that the effective resistance increases when the number of resistors connected in series increases (i) state that the effective resistance decreases when the number of resistors connected in parallel increases	• **Topic 2 Guide** • 2.1A Measuring Current Using a Multimeter • 2.1B Measuring Voltage Using a Multimeter • 2.1C Measuring Resistance Using a Multimeter • 2.1D Developing Your Understanding • 2.2A Drawing and Interpreting Circuit Diagrams • 2.2B Developing Your Understanding • 2.3A Current in Series and Parallel Circuits

(j) explain the advantages of connecting household appliances in parallel (k) identify voltage rating and power rating found on a label of an electrical appliance (l) recall and apply the relationship *power* = *current* x *voltage* to solve problems (m) calculate the cost of using electrical appliances where the energy unit is the kW h (n) identify electricity usage found on an electricity bill (o) state some ways to reduce electrical energy wastage in daily lives (e.g., use energy-efficient appliances) (p) demonstrate ways and appreciate the need to reduce energy wastage (q) appreciate science for its usefulness in improving quality of life: knowledge of electricity helps us power machines	• 2.3B Voltage in Series and Parallel Circuits • 2.3C Resistance in Series and Parallel Circuits • 2.3D Circuits in a Home • 2.3E Developing Your Understanding • 2.4A Comparing Ratings and Calculating Power • 2.4B Developing Your Understanding • 2.5A Understanding the Consequences of Our Electricity Use • 2.5B Developing Your Understanding • Mastering Your Learning

3. WAVE

Topic Description

A wave is a disturbance that transfers ***energy*** from one place to another. It can be generated through vibrations. For example, wave motion can be generated with a rope by moving one end up and down. Amplitude, frequency and wavelength are some terms used to describe wave motion and they may ***change*** according to how the wave is generated.

There are ***diverse*** types of waves, such as microwaves and X-rays. They help us in areas such as communication and medical care.

Content

- Describing wave generation
- Wave terms
- Applications of waves

Key Inquiry Question

- How do we use waves to make our lives better?

Suggested *Core Ideas*

- Change
- Diversity
- Energy

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values, Ethics and Attitudes*	Suggested Learning Experiences
(a) describe how waves can be generated by vibrations, as illustrated by wave motion in ropes and springs (the terms longitudinal and transverse are not required) (b) show an understanding that waves transfer energy (c) show an understanding of the terms *amplitude*, *frequency* and *wavelength* used to describe wave motion (d) state some uses of the following types of waves: (i) radio waves (e.g. radio and television communications) (ii) microwaves (e.g. microwave oven, satellite communication) (iii) infrared (e.g. remote-controlled devices) (iv) light (e.g. optical fibres for telecommunication) (v) ultraviolet (e.g. sterilisation, sunbeds) (vi) X-rays (e.g. engineering and radiological applications) (vii) gamma rays (e.g. medical treatment)	• **Topic 3 Guide** • 3.1A Making Waves with a Slinky • 3.1B Developing Your Understanding • 3.2A Making Water Waves I • 3.2B Making Water Waves II • 3.2C Developing Your Understanding • 3.3A Infrared Applications • 3.3B Developing Your Understanding • Mastering Your Learning

(e) appreciate science for its usefulness in improving quality of life: knowledge of waves helps us understand how waves are used in areas such as communication and medical care	

4. EFFECTS OF FORCE

Topic Description
A force is a push or a pull. Although forces cannot be seen, many of their effects are observed in our daily lives.

A force can ***change*** the motion of an object, which can be described in terms of its speed and acceleration. The motion of the object can also be represented on a distance-time graph. For example, the weight of an apple (a force) causes it to break off a tree and accelerate as it falls to the ground. In other words, the speed, or distance travelled per unit time, of the apple increases with time.

A force can also bring about turning effect of an object. For example, applying a force on a doorknob may cause the door to turn about its hinges.

Content
- Effects of force
- Speed and acceleration
- Distance-time graph

Key Inquiry Question
- How do we use effects of force to make our lives better?

Suggested *Core Ideas*
- Change

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values*, *Ethics and Attitudes*	Suggested Learning Experiences
(a) use a ruler and a measuring tape to measure length (b) use a digital stopwatch to measure time interval (c) show an understanding of the following effects of force: (i) change in shape and/or size of an object (ii) change the state of rest or motion of an object (including change in speed and/or direction) (iii) bring about turning effect of an object (d) show an understanding of what is meant by speed and acceleration (e) recall and apply the relationship *average speed* = *total distance* / *total time taken* to solve problems (f) recall and apply the relationship *acceleration* = *change in speed* / *time taken* to solve problems (for motion in one direction only) (g) plot and interpret a distance-time graph (h) describe the moment of a force in terms of its turning effect and relate this to everyday examples (knowledge of equations is **not** required) (i) appreciate science for its usefulness in improving quality of life: knowledge of effects of force helps us understand how machines work	• **Topic 4 Guide** • 4.1A Developing Your Understanding • 4.2A Measuring Length • 4.2B Making a Water Clock • 4.2C Finding the Speed of a Moving Marble • 4.2D Developing Your Understanding • 4.2E Distance-Time Graphs • 4.2F Using Force to Change the State of Rest of Motion of an Object • 4.2G Developing Your Understanding • 4.3A Moments in Our Daily Lives • 4.3B Developing Your Understanding • Mastering Your Learning

Module 5
FOOD MATTERS

Overview

We need food to survive as it provides energy and nutrients required by our body. Plants are an important source of food and there are different ways to increase their production. For example, hydroponic farms in Singapore grow vegetables in nutrient-rich solutions, which help vegetables grow quickly.

Food is often processed before they are consumed. When making a lemon cake, freshly-squeezed lemon juice is passed through a sieve, where the seeds are removed. The acidic lemon juice is then added to a mixture with self-raising flour. Acid and baking soda (carbonate) in the mixture react to produce carbon dioxide, which causes the mixture to rise when it is heated. Food additives, such as food colourings, can be added to enhance the appearance of the cake.

Chemical changes due to the action of microbes may cause food spoilage. There are different ways to ensure that our food is safe for consumption over a longer period of time. For example, pickled vegetables, which pH is lowered by acid, have a longer shelf life than fresh or cooked vegetables.

Key Inquiry Questions

- How do we produce enough food for the population?
- How do we use separation techniques and chemical reactions to make our lives better?
- How do we ensure that our food is safe to eat?

5. SOURCES OF FOOD

Topic Description

Plants are an important source of food for us. They need air, light, water, nutrients and an appropriate pH for photosynthesis and growth. Farmers use fertilisers to improve the growth of plants, as well as pesticides and herbicides to protect plants against pests and weeds. However, these practices may have negative impact and lead to ***changes*** on the environment. For example, fertilisers can pollute groundwater and water bodies.

Given the growing world population and the limitation in space to grow food, we need to further harness technology in food production. Farmers are starting to tap on technologies to improve varieties of plants and animals. However, we need to strike a ***balance*** between feeding the population and protecting our environment.

Content

- Growing plants
- Food production

Key Inquiry Question

- How do we produce enough food for the population?

Suggested *Core Ideas*

- Balance
- Change

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values, Ethics and Attitudes*	Suggested Learning Experiences
(a) state that plants need air, light, water, nutrients and appropriate pH for photosynthesis and growth (b) show an understanding that the increase in world population and the limitation in space to grow food lead to the need to improve food production (c) describe how the following methods improve crops produced: (i) use of fertilisers (ii) use of pesticides and herbicides (iii) slash-and-burn (d) describe the environmental problems associated with the following methods: (i) use of fertilisers (water contamination leading to increased growth of algae and water weeds) (ii) use of pesticides and herbicides (soil and water contamination leading to transfer of harmful substances along the food chain) (iii) slash-and-burn method (haze leading to breathing difficulties and deforestation leading to soil erosion) (e) explain how the use of biological control reduces the need for pesticides (limited to control of prey by their predators)	• **Topic 5 Guide** • 5.1A Acidity and Alkalinity of Soil • 5.1B Developing Your Understanding • 5.2A How Do Fertilisers Help Plants Grow? • 5.2B Environmental Problems from Use of Fertilisers • 5.2C Environmental Problems from Use of Pesticides and Herbicides • 5.2D Environmental Problems from Slash-and-Burn • 5.2E Developing Your Understanding • 5.3A How to Ripen Bananas Quickly • 5.3B Developing Your Understanding • Mastering Your Learning

(f) describe how food production can be improved by: (i) improving varieties of plants and animals (ii) intensive farming methods for crops and farm animals (e.g. chicken, fish) [details of technologies are not required] (g) state that plant hormones are used as weed killers, and in regulating growth and ripening of fruits (h) appreciate science for its usefulness in improving quality of life: knowledge of science and technology to improve food production (i) show an awareness of the ethical and social issues related to the use of science and technology to improve food production	

6. FOOD CHEMISTRY

Topic Description

Processing of food often involves ***changes*** of ***matter***. Food substances in mixtures are extracted using appropriate separation techniques. For example, distillation is used to extract essential oil from orange peels.

Food substances contain ***diverse*** types of chemicals that have different properties. Acid is a common type of chemical found in sour food.

Different chemicals in food substances may react to form new substances. For example, an acid reacts with an alkali to produce salt and water. These chemical reactions may also affect the taste of food. For example, the acid and carbonate in fizzy candies react to produce carbon dioxide, which makes bubbles that pop in our mouths.

Content

- Separation techniques
- Acids and bases

Key Inquiry Question

- How do we use separation techniques and chemical reactions to make our lives better?

Suggested *Core Ideas*

- Change
- Diversity
- Matter

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values*, *Ethics and Attitudes*	Suggested Learning Experiences
(a) use a measuring cylinder to measure volume of liquid/solid (b) explain that substances can be separated from a mixture through the following techniques: (i) dissolving (ii) filtration (iii) evaporation (iv) distillation (v) paper chromatography (c) state some uses of separation techniques in homes and food industries (e.g. remove tea leaves from a cup of tea, obtain water from seawater) (d) describe a chemical reaction as a process that leads to the formation of new products (e) state the following everyday changes that involve chemical reactions and how they can be slowed down: (i) decaying of food slowed down by food preservation methods (see also LO 7(d))	• **Topic 6 Guide** • 6.1A Measuring Volume of Liquids and Solids • 6.1B Separating Sand from a Salt • 6.1C Separating Water from a Solution [Teacher Demonstration] • 6.1D What Is in Coloured Candies? • 6.1E Developing Your Understanding • 6.2A Identifying Chemical Reactions • 6.2B How Can We Slow Down the Process of Burning? • 6.2C How Can We Slow Down the Process of Rusting?

(ii) cooking of food and burning of fuel slowed down by reducing oxygen/fuel supply (iii) rusting of iron cans slowed down by tin-plating (f) describe the properties of acids and alkalis in terms of their effects on litmus paper and universal indicator solution (g) use universal indicator solution and a pH meter to measure pH (h) describe acidity, neutrality and alkalinity in terms of the pH scale (i) describe the characteristic properties of acids in terms of their reactions with metals, bases and carbonates that are found in daily lives: (i) metals (e.g. cooking utensil) (ii) bases (e.g. toothpaste, antacid) (iii) carbonates (e.g. baking soda, effervescent vitamin C tablet) [knowledge of general products is required; chemical names of salts and equations are **not** required] (j) state that neutralisation takes place when an acid reacts with a base and the products can be salt and water only (k) appreciate science for its usefulness in improving quality of life: knowledge of chemical reactions and separation techniques helps us understand how substances are processed in the food industry	• 6.2D Developing Your Understanding • 6.3A Testing for Acids and Alkalis • 6.3B Reactions of Acids • 6.3C Developing Your Understanding • Mastering Your Learning

7. FOOD SAFETY

Topic Description

Food spoilage is a ***change*** from the food's normal state. It may be due to the action of microbes, such as bacteria and mould. There are ***diverse*** methods to stop or reduce microbial activity to ensure that our food is safe for consumption over a longer period of time. The use of high or low temperature, and the reduction of oxygen, pH and water content are some methods that are commonly used in the food industry to prevent food spoilage.

Food preservatives prevent food spoilage. It is one of many types of food additives. Other types of food additives include nutrient supplements, and texture and appearance modifiers.

Content

- Food preservation
- Food additives

Key Inquiry Question

- How do we ensure that our food is safe to eat?

Suggested *Core Ideas*

- Change
- Diversity

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values, Ethics and Attitudes*	Suggested Learning Experiences
(a) state what microbes are (b) describe the action of microbes on food (e.g. bacteria on milk, mould on bread) (c) state that stopping or reducing microbial activity may prevent food spoilage (d) describe the following methods of preventing food spoilage and give example(s) for each of them: (i) lowering pH (pickling) (ii) reducing oxygen supply (bottling and vacuum packaging) (iii) reducing water content (freeze-drying, dehydration and use of chemical preservatives) (iv) using high temperature (sterilisation, pasteurisation and canning) (v) using low temperature (freezing) (e) explain the use of the following food additives and give examples for each of them: (i) preservatives (e.g. salt, sugar, sulfur dioxide, vinegar) (ii) nutritional supplements (e.g. minerals, vitamins) (iii) texture and appearance modifiers (e.g. food colourings, starch) (f) show an awareness of the harmful effects of the excessive use of food additives	• **Topic 7 Guide** • 7.1A Which Milk Is Spoilt? • 7.1B There Is Something on My Bread! • 7.1C Developing Your Understanding • 7.2A Protect My Bread! • 7.2B Developing Your Understanding • 7.3A Vitamin Content in Beverages • 7.3B Developing Your Understanding • Mastering Your Learning

(g) appreciate science for its usefulness in improving quality of life: knowledge of food spoilage helps us find ways of preventing food spoilage and reducing food wastage	

Module 6
OUR BODY AND HEALTH (II)

Overview

For our body to function normally, we need to stay healthy by adopting an active lifestyle, eating a balanced diet, having sufficient rest, practising good hygiene and making informed lifestyle decisions (e.g., avoid smoking). For example, unhealthy diets and inactive lifestyles have led to an increase in the number of Singaporeans suffering from diabetes, which can eventually lead to disabilities and other diseases (e.g., kidney failure).

Our body is made up of different systems that work together to keep us alive. Our digestive system breaks down the food we eat into smaller substances with the help of enzymes. Our respiratory system takes in oxygen when we breathe. Blood in our circulatory system transports digested food substances and oxygen to all parts of our body. Our cells undergo respiration to release energy from food, allowing us to live, work and play.

Although our knowledge of the human body and medical technology (e.g., kidney dialysis) has improved our quality of life, there are limitations. Hence, we must take responsibility for our physical health.

Key Inquiry Questions

- How do we stay healthy?
- How does our digestive system keep us alive?
- How does our respiratory system keep us alive?
- How does our circulatory system keep us alive?

8. STAYING HEALTHY

Topic Description

We should adopt an active lifestyle, eat a ***balanced*** diet, have sufficient rest and practise good hygiene to stay healthy or to have a positive ***change*** in our physical health.

An indicator of physical health is the body mass index (BMI). When our BMI is not in the healthy range, we are more likely to develop health issues. However, we must also recognise the health risks of undereating and over-exercising in our attempt to lose weight. For example, over-exercising without sufficient rest may lead to problems related to bones and joints.

Microbes can cause diseases but we can harness technology to fight them. Antimicrobial agents, such as antiseptics and disinfectants, reduce the population growth of microbes. Hence, we should wash our hands with antimicrobial agents when necessary to maintain good hygiene. Although some diseases caused by bacteria and viruses may be prevented by vaccinations, only diseases caused by bacteria can be treated using prescribed courses of antibiotics. When organs malfunction due to diseases, we use technology to replace or support them (e.g. organ transplant, kidney dialysis) but there are limitations.

Content

- Maintaining good physical health
- Problems related to bones and joints

Key Inquiry Question

- How do we stay healthy?

Suggested *Core Ideas*

- Balance
- Change

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values*, *Ethics and Attitudes*	Suggested Learning Experiences
(a) state the following ways in maintaining good physical health: (i) adopting an active lifestyle (ii) eating a balanced diet (iii) having sufficient rest (iv) practising good hygiene (b) show an understanding of what is meant by a balanced diet (c) state the dietary importance of carbohydrates, dietary fibre, fats, proteins, minerals (calcium), vitamins (vitamin D) and water (d) recall and determine the body mass index, *BMI = mass (kg) / [height (m) x height (m)]* to deduce whether an individual's mass is in the healthy range (e) describe the health risks of undereating and over-exercising to lose weight	• **Topic 8 Guide** • 8.1A Lifestyle Choices and Our Health • 8.1B Planning My Meals • 8.1C Developing Your Understanding • 8.2A Calculating BMI • 8.2B Undereating and Over-Exercising • 8.2C Developing Your Understanding • 8.3A Parts of a Joint [Teacher Demonstration] • 8.3B Problems Related to Bones and Joints

(f) describe the following problems related to bones: fracture and osteoporosis (g) state the following parts associated with common joints and their functions: cartilage and ligament (h) describe the following problems related to parts associated with joints: arthritis, dislocation and sprain (i) state how diet and level of physical activity can affect the risk of developing problems related to bones and joints (j) state that diseases can be used by bacteria or viruses (structures of bacteria and viruses are **not** required) (k) describe the effects of antimicrobial agents (e.g. antiseptics, disinfectants) on the population growth of microbes (e.g. bacteria, fungi) (l) explain the importance of completing a prescribed course of antibiotics for diseases caused by bacteria (m) state that diseases caused by bacteria and viruses may be prevented by vaccinations (n) state that some diseases/conditions are hereditary by nature (e.g. sickle cell disease, thalassemia, colour deficiency) (o) state some limitations of the use of technology in replacing or supporting malfunctioning organs (e.g. tissue rejection after organ transplant, lifelong dependence on kidney dialysis) (p) show an awareness of the ethical and/or social issues related to the use of technology in replacing or supporting malfunctioning organs (q) show care and concern for personal health by adopting an active lifestyle, eating a balanced diet, having sufficient rest and practising good hygiene to reduce the risk of developing diseases (r) show care and concern for personal health by avoiding undereating and over-exercising to lose weight (s) appreciate science for its usefulness in improving quality of life: knowledge of science (e.g. bones and joints) helps us make informed decisions about our health	• 8.3C Taking Care of Bones and Joints • 8.3D Developing Your Understanding • 8.4A Effects of Antimicrobial Agents on the Growth of Microbes • 8.4B Managing Diseases and Conditions • 8.4C Managing Malfunctioning Organs • 8.4D Developing Your Understanding • Mastering Your Learning

9. DIGESTION

Topic Description

Our digestive ***system*** breaks down the food we eat into smaller substances for absorption into our bloodstream, to provide ***energy***. Enzymes released into our mouth, stomach and small intestine speed up the rate of digestion most when they are functioning at their optimum pH and temperature. For example, our pancreas releases enzymes into our small intestine to digest carbohydrates, proteins and fats. These enzymes function well in alkaline conditions and at normal body temperature.

Diet, level of physical activity and alcohol consumption may ***change*** the health of our digestive system. For example, a diet lacking in dietary fibre can increase our risk of developing constipation.

Content

- Digestive system
- Problems related to digestive system

Key Inquiry Question

- How does our digestive system keep us alive?

Suggested *Core Ideas*

- Change
- Energy
- System

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values, Ethics and Attitudes*	**Suggested Learning Experiences**
(a) explain the importance of digestion (b) identify the following main organs and associated organs of the digestive system, and state their functions: mouth, gullet, stomach, small intestine, large intestine, rectum, anus, salivary glands, pancreas, liver and gall bladder (c) show an understanding that enzymes speed up the rate of digestion and require an optimum temperature and pH to work efficiently (names of enzymes and substrates are not required) (d) interpret data on the effect of pH and temperature on the rate of digestion by enzymes (e) explain why constipation occurs and state possible preventive measures (f) state the effects of excessive alcohol consumption on the liver (e.g. damaged liver, liver cancer) (g) state how diet and level of physical activity can affect the risk of developing diabetes (h) demonstrate ways to avoid alcohol abuse and to discourage others from alcohol abuse (i) show care and concern for personal health by adopting an active lifestyle and eating a balanced diet to reduce the risk of developing diabetes	• **Topic 9 Guide** • 9.1A Taking in Food • 9.1B Developing Your Understanding • 9.2A Effects of Acid on Food • 9.2B Breaking up Oil • 9.2C Making a Model of the Digestive System • 9.2D Developing Your Understanding • 9.3A Enzyme in Digestion • 9.3B Effect of Temperature on Rate of Digestion • 9.3C Developing Your Understanding • 9.4A What Happens to Each Nutrient? • 9.4B Developing Your Understanding

(j) appreciate science for its usefulness in improving quality of life: knowledge of our digestive system helps us make informed decisions about our health	• 9.5A How Alcohol Affects Our Liver • 9.5B Understanding Diabetes • 9.5C Developing Your Understanding • Mastering Your Learning

10. BREATHING

Topic Description

Breathing is the process of taking in and removing air from our lungs. The air that we inhale contains oxygen, which is required for respiration to take place to release ***energy*** from the digested food. Carbon dioxide produced during respiration is removed when we exhale. The ***changes*** in the composition of air within our respiratory system keep us alive.

Smoking and passive smoking affect the health of our respiratory ***system***. For example, smoking can increase the risk of developing bronchitis, causing the smoker to have breathing difficulties.

Content

- Respiratory system
- Effects of smoking

Key Inquiry Question

- How does our respiratory system keep us alive?

Suggested *Core Ideas*

- Change
- Energy
- System

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values*, *Ethics and Attitudes*	Suggested Learning Experiences
(a) describe the roles of breathing and respiration in keeping humans alive (b) identify the following parts of the respiratory system and state their functions: windpipe, bronchi, lungs, diaphragm and ribcage (c) explain the differences in the composition of inhaled and exhaled air (d) use simple tests for: (i) carbon dioxide (limewater test) (ii) water vapour (cobalt chloride paper test) [knowledge of detailed procedures of tests is not required] (e) explain how choking affects breathing (f) state the effects of smoking and passive smoking on the respiratory system (e.g. bronchitis, lung cancer) (g) demonstrate ways to avoid smoking and to discourage others from smoking (h) appreciate science for its usefulness in improving quality of life: knowledge of our respiratory system helps us make informed decisions about our health	• **Topic 10 Guide** • 10.1A Comparing Inhaled Air and Exhaled Air • 10.1B Developing Your Understanding • 10.2A This Is How We Breathe • 10.2B Developing Your Understanding • 10.3A How Smoking Affects Us • 10.3B Developing Your Understanding • Mastering Your Learning

11. BLOOD CIRCULATION

Topic Description

Our circulatory ***system*** enables blood to circulate and transport oxygen, digested food substances, carbon dioxide and waste substances to and from different parts of our body. There are different components in our blood, and they serve different functions. For example, red blood cells carry oxygen, which is required for respiration, from our lungs to other parts of our body. White blood cells destroy bacteria, which might be harmful to our body.

Blood pressure, heart rate and pulse rate can be used to monitor the health of our circulatory system, which may be ***changed*** by diet, level of physical activity and smoking. For example, having a diet with high cholesterol may cause the formation of plaque in our blood vessels, increasing our risk of developing heart attack and stroke.

Content

- Circulatory system
- Problems related to circulatory system

Key Inquiry Question

- How does our circulatory system keep us alive?

Suggested *Core Ideas*

- Change
- System

Learning Outcomes that bring about *Core Ideas*, *Practices of Science* and *Values*, *Ethics and Attitudes*	Suggested Learning Experiences
(a) state the following components of blood: plasma, platelets, red blood cells and white blood cells (b) state the role of blood and its following components in transport and defence: (i) plasma – transport of digested food substances and waste substances (carbon dioxide) (ii) platelets – clotting of blood (iii) red blood cells – transport of oxygen (iv) white blood cells – antibody formation, destruction of bacteria and viruses, and tissue rejection (c) outline the pathway of blood through the heart and the lungs in relation to the transport of oxygen and carbon dioxide (d) state the structure of arteries, veins and capillaries, and relate it to their functions (e) state that blood pressure, heart rate and pulse rate can be used to monitor the condition of the circulatory system (f) explain why breathing rate, heart rate and pulse rate increase during physical activities (g) describe how the formation of plaque leads to heart attack and stroke (h) state how diet, level of physical activity and smoking can affect the risk of developing heart diseases, high blood pressure and stroke	• **Topic 11 Guide** • 11.1A Model of the Circulatory System • 11.1B Structures of Blood Vessels • 11.1C Developing Your Understanding • 11.2A Viewing Blood Cells • 11.2B Roles of Red Blood Cells, White Blood Cells and Platelets • 11.2C Developing Your Understanding • 11.3A Effect of Exercise on Pulse Rate • 11.3B Developing Your Understanding • 11.4A Clearing a Path to the Heart • 11.4B Who Is at Risk? • 11.4C Developing Your Understanding • Mastering Your Learning

(i) show care and concern for personal health by adopting an active lifestyle, eating a balanced diet and avoiding smoking to reduce the risk of developing high blood pressure, heart diseases and stroke (j) appreciate science for its usefulness in improving quality of life: knowledge of our circulatory system helps us make informed decisions about our health	

SECTION 3: PEDAGOGY

Teaching and Learning of Science
Students as Inquirers
Blended Learning
Teachers as Facilitators
Use of ICT
Designing STEM Learning Experiences in Science

3. PEDAGOGY

3.1 Teaching and Learning of Science

We believe that all children are curious and want to explore and learn about things around them. The science curriculum leverages and seeks to fuel this spirit of curiosity 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 of Science* and cultivating *Values, Ethics and Attitudes*.

These experiences can be situated in authentic contexts in both formal and informal learning platforms and should inspire students to inquire and innovate. In enacting 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 provided by teachers as part of Assessment for Learning (AfL).

Learning of science will not be complete without the incorporation of hands-on learning, which develops in students the ways of thinking and doing while supporting their development of scientific knowledge.

3.2 Students as Inquirers

For students to be inquirers, their thinking skills and dispositions should be developed as part of their learning experiences. Students 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

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

- <u>gather evidence to respond to their questions</u>. They gather evidence through observations and collect qualitative or quantitative data using simple instruments. After the data collection, they present the evidence in appropriate forms (e.g., tables, charts, graphs) to facilitate the analysis of patterns and relationships. Students can also use the Internet to source for information.

- <u>formulate explanations based on the evidence gathered</u>. They explain their findings with integrity, based on scientific concepts and the evidence gathered (e.g., qualitative descriptions of observations or quantitative data collected over a time interval).

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

- communicate and justify their explanations. They communicate using various types of representations to facilitate the analysis of patterns and relationships. For example, they can use texts, drawings, charts, tables, graphs 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). 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 4**).

Figure 4: Examples of Blended Learning experiences

Table 6: Elaboration of possible 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

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. This can be done through the contextualised learning approach where teachers use the contexts in the modules to facilitate students' understanding and appreciation of the relevance of scientific concepts in their daily 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/phenomena/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 evidence gathered;
- encourage students to apply concepts learnt in understanding daily events/phenomena, finding solutions to problems/issues and creating products; and
- check on students' understanding to ascertain if learning has taken place, provide appropriate and meaningful feedback to address students' learning gaps, and guide students to act on the feedback provided.

The *Pedagogical Practices* in the STP, as shown in **Figure 5**, 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.

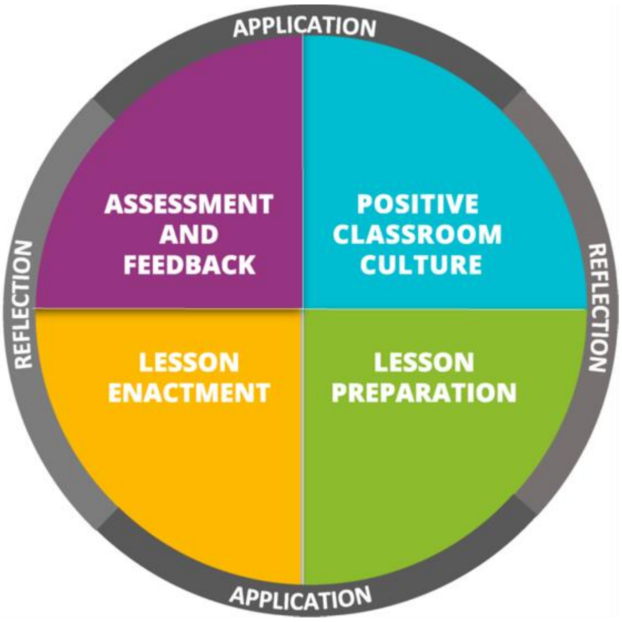


Figure 5: The four core Teaching Processes within the Pedagogical Practices in STP

3.5 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.

3.5.1 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.

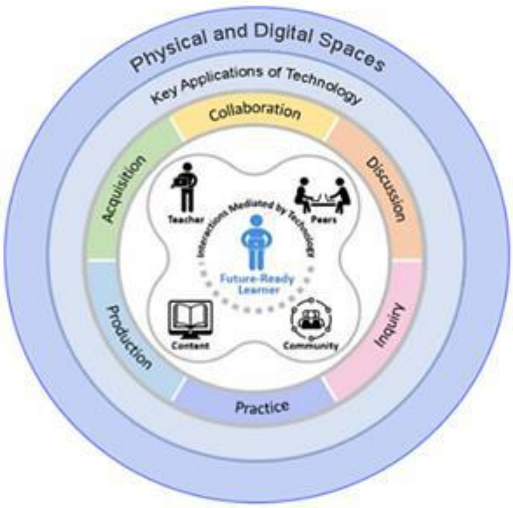


Figure 6: Overview of e-Pedagogy

The EdTech Pedagogical Scaffold (PS) is a tool to guide teachers in applying e-Pedagogy. It translates e-Pedagogy into five key actions that guide teachers in designing and facilitating active learning with technology.

Teachers can be guided by the Key Applications of Technology 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.

3.5.2 Technology for Active Learning

In the Upper Secondary Science Normal (Technical) syllabus, students will learn science actively through the Digital Learning Materials on SLS. The lesson packages are designed based on strong organising schemas to support students' learning. They feature curriculum-aligned content, multi-modal representations of scientific concepts through the use of rich media objects, such as videos, animations and interactives (VAI), and opportunities for interactions and timely feedback, catering to diverse student needs. The flexible organisational architecture of the Digital Textbook allows teachers to customise the lesson packages depending on the learning needs of students to support differentiated instruction for students. Additionally, the learning experiences on SLS enable interactions mediated by technology, which support student agency as students curate, annotate, create and share digital content, and receive feedback from teachers and peers.

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).

3.5.3 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 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.

3.6 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 7**.

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 7: 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 is one of the ways for schools to review the effectiveness of their instructional programme.

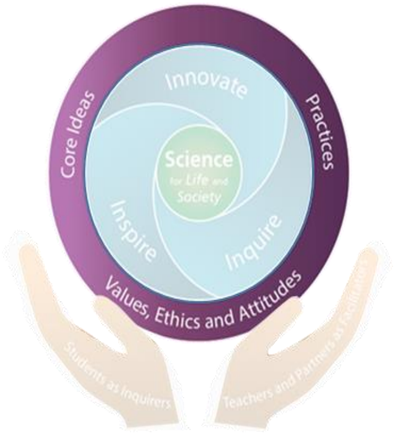
- Assessment provides feedback to **parents**. It allows them to monitor their children's learning attainment and progress through the information obtained.

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.

<u>What to Assess?</u>

The Upper Secondary Science Normal (Technical) curriculum is designed using the contextualised approach and aims to develop 21CC and scientific literacy in students.



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.

How to Assess?

As assessment serves many purposes, it is guided by the specific purpose for which it is intended. Before making an assessment about a certain aspect of students' learning, teachers should ensure that the form of assessment used will generate information that reflect accurately the aspect of learning teachers intend to assess. Assessment should, where possible, include items with real-world contexts and incorporate the affordances of ICT.

Different forms of assessment should be used to assess different aspects of learning. In addition to written assessments, teachers should conduct performance-based assessments, which may include:

- Debates
- Drama/ Show and Tell
- Learning Trails
- Model-making
- Portfolio
- Posters
- Practical work
- Projects
- Reflections/ Journals

For example, teachers can assess students through the use of portfolio. It is a systematic and purposeful collection of students' work and provides a more comprehensive picture of their learning. The work collected provides a continuous record of the students' development and progress in the acquisition of *Core Ideas*, *Practices of Science* as well as *Values, Ethics and Attitudes* to develop 21CC. In addition, the portfolios can be compiled to showcase students' learning. Students have the opportunity to self-evaluate by deciding which pieces of work they want to compile into their portfolio. They can also carry out reflections by revisiting their own portfolio to ascertain their mastery of the relevant 21CC.

The use of digital platforms for assessment can complement pen-and-paper assessment to better assess students' attainment of the intent of the curriculum. By tapping on the affordance of digital resources, assessment can be made more meaningful and better inform teaching practices to guide students in developing strong fundamentals in science. The use of multi-modal media, such as VAI, provides opportunities for students to demonstrate scientific understanding and *Practices of Science* (e.g., interpreting and evaluating observations that vary with time) that are not easily captured. It also allows real-world contexts introduced in the assessment task to be better understood by students without increasing their reading load. To ensure the effective use of these media in assessment tasks, some design principles should be considered. These include deciding the visual design (e.g., colour, size and scale of elements), managing the complexity of the media, selecting the context to situate the media and choosing the strategy of response for the task.

Designing assessment tasks that are fit for purpose should undergird the choice of the form of assessment.

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.

As described in the Singapore Teaching Practice (STP), assessment and feedback is one of the four Teaching Processes and can be broken down into three teaching areas:

Table 7: Three teaching areas of assessment and feedback

Teaching Area	Descriptor
Checking for Understanding and Providing Feedback	Teachers determine the extent of students' understanding in relation to the lesson objectives. The evidence and information gathered guide subsequent instruction and allow teachers to provide specific feedback to students. In turn, this helps students to know the next steps needed to achieve the lesson objectives.
Setting Meaningful Assignments	Teachers set meaningful assignments to reinforce or to extend students' learning. Meaningful assignments are guided by lesson objectives. When appropriately set, these assignments provide opportunities for students to apply their learning, and challenge them to think critically and creatively.
Supporting Self-directed Learning	Teachers facilitate student reflection and self-directed learning to encourage deep learning. Through teachers' facilitation, students are guided to think about their own thinking and to reflect on the extent of their learning.

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 N(T)-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.

SECTION 5:
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5. ACKNOWLEDGMENTS

Members of the Upper Secondary Science Normal (Technical) Syllabus and Resource Development Committee (2017 – 2022) are:

1. Ms Wang Siew Ping, Deputy Director, Sciences, Curriculum Planning and Development Division
2. Mr Chia Guo Hao, Senior Assistant Director, Sciences, Curriculum Planning and Development Division (up to 2017)
3. Ms Chua Shi Qian, Senior Assistant Director, Sciences, Curriculum Planning and Development Division (up to 2021)
4. Dr Chin Tan Ying, Assistant Director General Science/Master Specialist, Sciences, Curriculum Planning and Development Division
5. Mr Aaron Ye, Assistant Director, Sciences, Curriculum Planning and Development Division (up to 2021)
6. Mr Lim Kangyu, Assistant Director, Sciences, Curriculum Planning and Development Division
7. Dr Paul Chua, Principal/Special Projects, Sciences, Curriculum Planning and Development Division (up to 2018)
8. Assoc Professor Teo Tang Wee, Natural Sciences and Science Education Academic Group, National Institute of Education
9. Mr Mohamed Nizamudeen Bin Abdul Rahman, Section Head/Precision Engineering-Advanced Engineering Processes, School of Engineering, Institute of Technical Education College Central (up to 2019)
10. Ms Kelly New, Section Head/Precision Engineering – Advanced Engineering Processes, School of Engineering, Institute of Technical Education College Central
11. Ms Yio Siew Hui Trionna, Section Head/Applied Food Science, School of Applied and Health Sciences, Institute of Technical Education College East
12. Ms Yvonne Lau, Section Head/Nursing, School of Applied and Health Sciences, Institute of Technical Education College East (up to 2018)
13. Ms Sanjyogita Shri Rammani, Senior Lecturer/Nursing, School of Applied and Health Sciences, Institute of Technical Education College East
14. Dr Diana Ng, Senior Assessment Specialist, Singapore Examination and Assessment Board (up to 2020)
15. Mr Tan Lee Sze, Senior Assessment Specialist, Singapore Examination and Assessment Board (up to 2020)
16. Ms Daphane Tan, Assessment Specialist, Singapore Examination and Assessment Board (up to 2020)
17. Dr Muhammad Nazir Bin Amir, Master Teacher/Educational Support, Academy of Singapore Teachers
18. Mr Kalvindar Singh, Vice-Principal, Yusof Ishak Secondary School (up to 2019)
19. Mr Gregory Peck Chin Hee, HOD/ICT, Serangoon Secondary School (up to 2019)
20. Mrs Liow-Lee Lay Suan, School Staff Developer, Bedok Green Secondary School (up to 2020)
21. Mdm Aznah Bte Hj Kilali, HOD/Special Project, St. Anthony’s Canossian Secondary School
22. Mr Mohamad Khirsyaban Iskandar, HOD/Science, Bedok Green Secondary School

23. Mr Ramesh s/o Ramalingam, Lead Teacher/Chemistry, Montfort Secondary School
24. Ms Ng Zhaoyue, Subject Head/Student Development, Tanglin Secondary School
25. Mr Lam Seng Tat, Teacher, Jurongville Secondary School
26. Mr Woo Kwong Hui Jacob, Teacher, Assumption English School
27. Mr Guo Xianlun, Teacher, Edgefield Secondary School
28. Mr Whey Kin Pheng, Teacher, Ping Yi Secondary School
29. Mdm Khoo Bee Chan, Assistant Director, Learning Partnership in Educational Technology, Educational Technology Division (up to 2020)
30. Mr Isaac Ng, Education Technology Officer, Educational Technology Division (up to 2017)
31. Ms Teo Wei Ting, Educational Technology Officer, Educational Technology Division (up to 2020)
32. Mr Chua Chiang Leong Gary, Educational Technology Officer, Educational Technology Division
33. Mr Benjamin Por, Assessment Policy and Practice Officer, Curriculum Policy Office (up to 2020)
34. Dr Leong Wei Shin, Lead Specialist, Assessment Policy & Practice, Curriculum Policy Office
35. Mr Mohamed Fahizel s/o M Egueyamarecar, Senior Educational Support Officer, Educational Support, Curriculum Planning and Development Division (up to 2018)
36. Ms Angeline Low, Educational Support Officer, Educational Support, Curriculum Planning and Development Division (up to 2020)
37. Ms Wong Wai Mun, Senior Educational Support Officer, Uplift and Educational Support Branch, Schools Division (up to 2021)
38. Mr Ang Yu Jian, Educational Support Officer, Uplift and Educational Support Branch, Schools Division
39. Mdm Liew Poh Yin, Lead Specialist, Sciences, Curriculum Planning and Development Division
40. Mdm Charlene Seah, Senior Curriculum Specialist, Sciences, Curriculum Planning and Development Division
41. Mdm Ramachandra Suguna, Senior Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division (up to 2017)
42. Mr David Oon, Senior Curriculum Resource Development Officer, Sciences, Curriculum Planning and Development Division (up to 2018)
43. Ms Wong Po San, Senior Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division (up to 2018)
44. Ms Ng Pei Sun, Senior Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division (up to 2019)
45. Ms Ferlynn Tan, Senior Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division (up to 2019)
46. Mr Clarence Chang, Curriculum Resource Development Officer, Sciences, Curriculum Planning and Development Division (up to 2019)
47. Ms Yap Xiao Jun, Curriculum Resource Development Officer, Sciences, Curriculum Planning and Development Division (up to 2019)
48. Ms Quek Shir Ryn, Curriculum Resource Development Officer, Sciences, Curriculum Planning and Development Division (up to 2019)
49. Ms Gerlynn Yap, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division (up to 2020)

50. Mr Koh Tat Siang, Curriculum Resource Development Officer, Sciences, Curriculum Planning and Development Division (up to 2020)
51. Ms Tong Shuqing, Curriculum Resource Development Officer, Sciences, Curriculum Planning and Development Division (up to 2020)
52. Mr Go Jun Hong, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division (up to 2021)
53. Ms Tan Yan Fen, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division (up to 2021)
54. Ms Reena Devi, Curriculum Resource Development Officer, Sciences, Curriculum Planning and Development Division (up to 2021)
55. Mr Eric Lee, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division
56. Ms Sabrina Amir Soh, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division
57. Ms Kristine Anne Koh, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division
58. Ms Neo Hui Jun, Senior Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division
59. Ms Tan Jialin Grace, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division
60. Mr Lee Khai Yin, Senior Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division
61. Mr Jeysthur Ang, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division
62. Ms Lim Wei San, Curriculum Planning Officer, Sciences, Curriculum Planning and Development Division

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