SCIENCE SYLLABUS

Lower Secondary

General 2 Course
General 3 Course

Implementation starting with
2021 Secondary One Cohort

Ministry of Education
SINGAPORE

CONTENTS

SECTION 1: INTRODUCTION

Science Curriculum Framework
Developing 21st Century Competencies Through Science
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1. INTRODUCTION

1.1 Science Curriculum Framework

The *Science Curriculum Framework* (**Figure 1**) encapsulates the thrust of science education in Singapore, which is to provide students with a strong foundation in science for life, future learning, citizenry and work.

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

Figure 1: Science Curriculum Framework

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

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

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

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

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

- <u>INquire like scientists</u>. Students have a strong foundation 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 are able to suspend judgement where there is lack of evidence.

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

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

- <u>*Core Ideas* (CI) of science</u>. *Core Ideas* (**Figure 2**) 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).

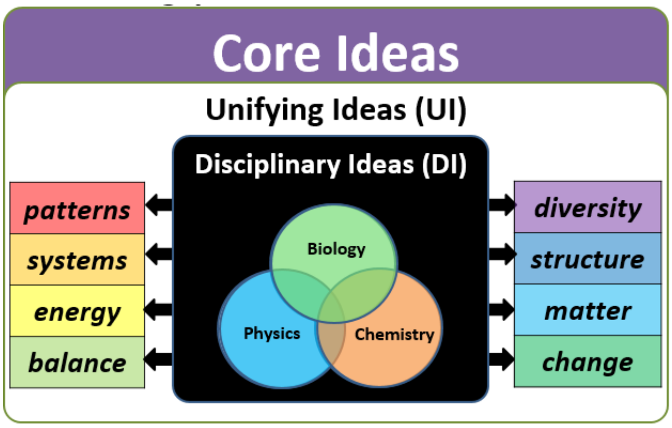

Figure 2: Diagram representing the Core Ideas in the Science Curriculum Framework

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

They represent the set of established procedures and practices associated with scientific inquiry, what scientific knowledge is and how it is generated and established, as well as how science is applied in society (**Figure 3**). The Practices serve to highlight that science is more than the acquisition of a body of knowledge (e.g. scientific facts, concepts, laws, and theories); it is also a way of thinking and doing. In particular, it is important to appreciate that the three components representing the cognitive, epistemic and social aspects of the Practices are intricately related.

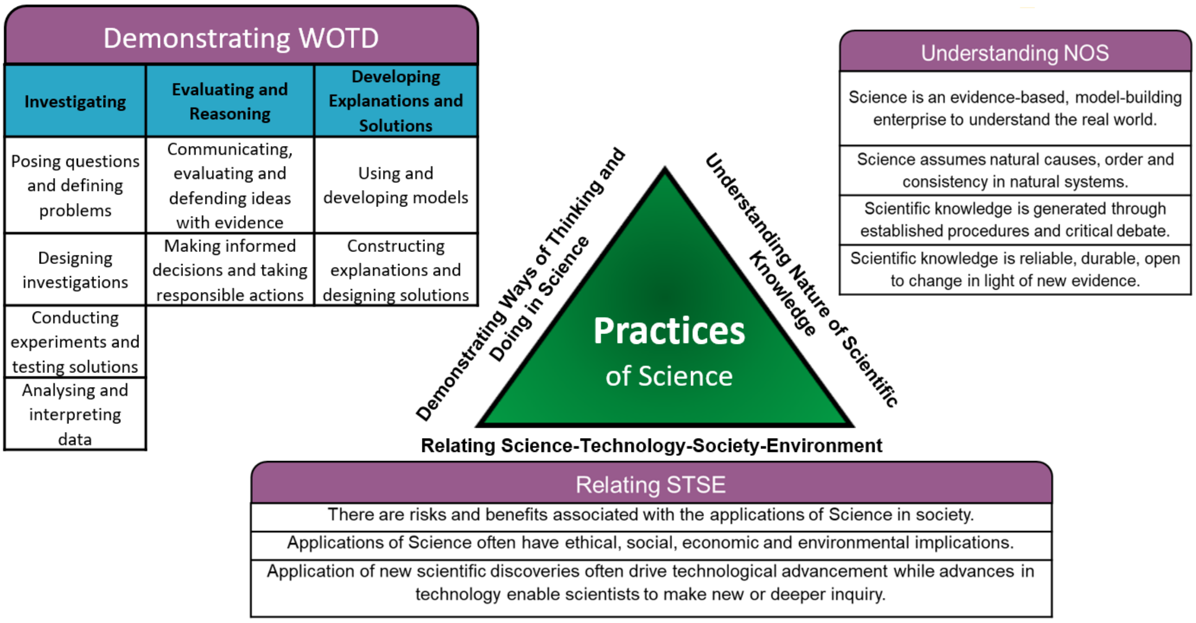

Figure 3: Diagram representing the Practices of Science in the Science Curriculum Framework

- <u>Values, Ethics and Attitudes (VEA) in science</u>. Although science uses objective methods to arrive at evidence-based conclusions, it is a human enterprise conducted in particular social contexts which involves consideration of values and ethics (**Table 1**). It is important for our students to be aware of and appreciate the values and ethical implications of the application of science in society. Thus, science education needs to equip students with the ability to articulate their ethical stance as they participate in discussions about socio-scientific issues that involve ethical dilemmas, with no single right answers.

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.

Table 1: Diagram representing the Values, Ethics and Attitudes in the Science Curriculum Framework

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 facilitate learning in various contexts to 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 (**Figure 4**). 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.

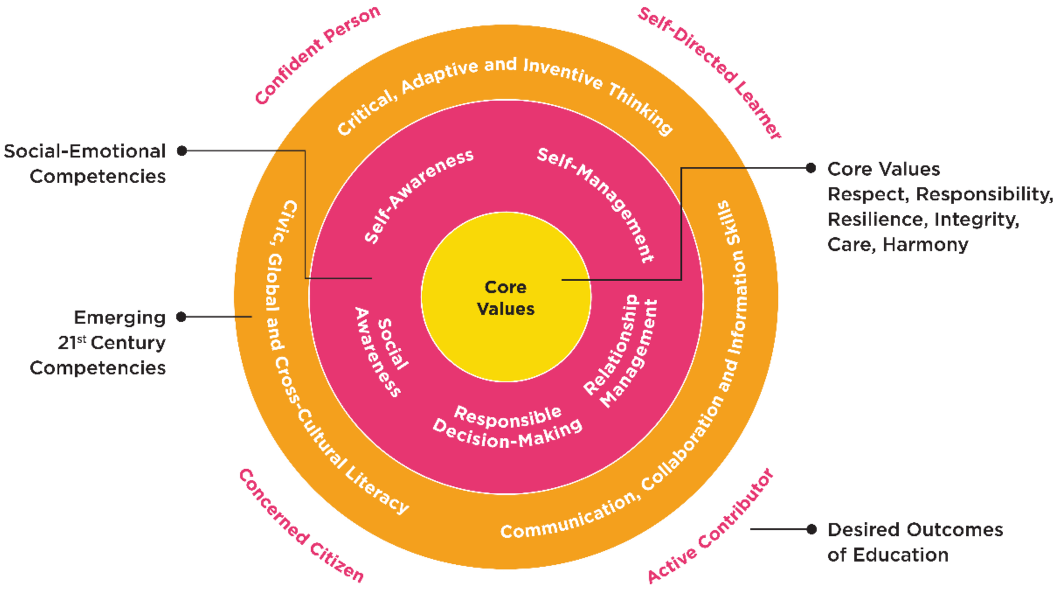

Figure 4: Framework for 21st Century Competencies and Student Outcomes

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 2** for specific examples).

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.

Developmental Milestone	Example of how it could look like in a secondary science classroom
• Use evidence and adopt different viewpoints to explain their reasoning and decisions. • Reflect on their thoughts, attitudes, behaviour, actions and draw on relevant cognitive strategies to determine and act on the modifications required.	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.

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.

Developmental Milestone	Example of how it could look like in a secondary science classroom
• Generate ideas that may involve modifying existing ones and explore different pathways that are appropriate to respond to an issue or challenge. • Evaluate and refine their ideas using relevant strategies and based on a set of criteria that is appropriate for the task or context.	Students could be given opportunities to: • design investigations to inquire into specific phenomena or solve issues set in authentic contexts, with considerations 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.

<table>
<tr><td colspan="2">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.</td></tr>
<tr><th>Developmental Milestone</th><th>Example of how it could look like in a secondary science classroom</th></tr>
<tr><td>• Convey and evaluate knowledge to co-construct new understandings and ideas coherently, while considering the specific purpose and context of communication.
• Respond with respect and empathy; is sensitive to the diverse backgrounds that influence different perspectives while interacting with others.
•</td><td>Students could 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.</td></tr>
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Table 2: Examples of 21CC development in science

1.3 Value and Aims of G2/G3 Lower Secondary Science

1.3.1. Value of G2/G3 Lower Secondary Science

As Lower Secondary Science (LSS) bridges Primary Science and Upper Secondary Science, LSS education needs to help students obtain baseline scientific literacy for basic citizenry **(Section 1.2 Developing 21st Century Competencies Through Science)**, and to equip students with a strong foundation to support their further studies. LSS continues the general science emphasis of Primary Science before students pursue the disciplinary subjects of physics, chemistry and biology at upper levels. This approach in LSS supports students in making connections across disciplines and solving interdisciplinary problems.

1.3.2. Aims of G2/G3 Lower Secondary Science

The aims of the G2/G3 Lower Secondary Science syllabuses are to:

a. **cultivate students' appreciation of science as a collective human endeavour to understand the natural world, and as a way of thinking rather than just a body of facts.**

   This involves promoting awareness that the study and practice of science are co-operative and cumulative activities. These activities are subject to social, economic, technological, ethical and cultural influences and limitations. In addition, the applications of science are generally beneficial, but the abuse of scientific knowledge can be detrimental.

b. **inspire students to make informed decisions and take responsible actions in science-related issues that concern their lives, the society and the environment**.

   This involves stimulating students' curiosity, interest and enjoyment in science and matters relating to science and technology as well as developing their care for the environment.

c. **help students develop in fundamentals that are integral to scientific inquiry and innovation, including problem-seeking and problem-solving**.

   These fundamentals include the (i) acquisition of Core Ideas, (ii) acquisition of the Practices of Science, and (iii) development of Values, Ethics and Attitudes relevant to science that would help students become confident citizens in a technological world.

SECTION 2: CONTENT

Syllabus Framework for G2/G3 Lower Secondary Science

2. CONTENT

2.1 Syllabus Framework

The G2/G3 Lower Secondary Science syllabuses comprise the Core Ideas, Practices of Science as well as Values, Ethics and Attitudes that all students should acquire to develop scientific literacy. The design of the syllabuses takes into account the time needed for the use of engaging teaching and learning approaches, and the implementation of customised school-based programmes that meet the aims of the syllabuses. This enables teachers to make learning more meaningful and enjoyable for students.

The features of the G2/G3 Lower Secondary Science syllabuses comprise:

a. <u>Thematic Narrative</u>

Guided by the Science Curriculum Framework, the G2/G3 LSS curriculum is underpinned by five themes, which is aligned to the Primary Science Syllabus. These themes arise from Core Ideas and Practices of Science, and provide the foundational concepts that students need for the disciplinary sciences (biology, chemistry and physics) at upper secondary. The five themes in the G2/G3 LSS syllabuses are: Scientific Endeavour, Diversity, Models, Interactions and Systems (**Table 3**).

Planned Curriculum		
1. The Scientific Endeavour		
Themes	**Topics**	
Diversity	2. 3. 4.	Exploring Diversity of Matter by its Physical Properties Exploring Diversity of Matter by its Chemical Composition Exploring Diversity of Matter using Separation Techniques
Models	5. 6. 7. 8.	Ray Model of Light Model of Cells - the Basic Unit of Life Model of Matter - The Particulate Nature of Matter Model of Matter - Atoms and Molecules
Interactions	9. 10. 11. 12.	Application of Forces and Transfer of Energy Transfer of Heat Energy and its Effects Chemical Changes Interactions within Ecosystems
Systems	13. 14. 15. 16.	Electrical Systems Human Digestive System Transport Systems in Living Things Human Sexual Reproductive System

Table 3: Overview of the G2/G3 Lower Secondary Science Syllabuses

The thematic narrative is supported by the contexts (Sustainability, Emerging Technologies, Climate Change and Science behind Healthcare) that reinforce the themes as well as the activities which elaborate on how the themes are related to the Core Ideas and Practices of Science. The thematic narrative consists of three components pertaining to: (1) *what*: which describes the scope of the theme; (2) *why*: which provides the purpose for studying this theme; and (3) *how*: which illustrates the learning experiences and contexts to the integrated experience that students can immerse in (**Figure 5**).

Theme: Diversity

What is "Diversity"?
There is a great variety of living and non-living things in the world. Classification helps us better *understand* the diversity of things in the world. Knowledge about the diversity of living and non-living things is reliable and durable. In light of new evidence that arises from technological advancements, this knowledge is open to change.

Why is the study of "Diversity" important?
In Science, we make sense of the complexity in the diversity of things in the world by organising them based on the common characteristics. This helps us understand and appreciate the similarities and uniqueness in things. However, some phenomena may not fit neatly into pre-determined categories. In cases of such exceptions, critical debate within the scientific community helps to make a considered judgment, guided by a set of established procedures and practices. Hence, we are able to understand the world around us better and, in turn, are inspired and empowered to improve life

How is an integrative experience for the theme like?
Building on what students learnt about the diversity of things in Primary Science, they will learn about the need to identify criteria for the different forms of matter.

Using the real-life context of sustainable living, students will appreciate and distinguish among the different physical properties and chemical composition of materials. They will then apply their understanding of materials through the use of various separation techniques.

Figure 5: Example of a Thematic Narrative in the Syllabus

b. Topic Descriptor

The topic descriptor (**Figure 6**) found after each topic title articulates the desired learning for students, and links the topic to its corresponding theme.

2. Exploring Diversity of Matter by its Physical Properties
Students will explore and learn about the different physical properties of materials. They learn to identify criteria for distinguishing characteristics that help them to understand the world. This will also enable them to make informed decisions on appropriate use of materials for everyday products/situations to increase efficiency, safety and sustainability.

Figure 6: Example of a Topic Descriptor in the Syllabus

c. Key Inquiry Questions and Essential Takeaways

The thematic narrative is complemented by the *Key Inquiry Questions* and the *Essential Takeaways*. The *Key Inquiry Questions* are used to cover the important ideas of the theme (**Figure 7**). The *Essential Takeaways* clarify what students should know about the theme at the end of all the topics in that theme (**Figure 8**).

Although this component of the syllabus is organised into five themes, the content and Essential Takeaways should not be viewed as compartmentalised blocks of knowledge.

In general, there are no clear boundaries among themes. There may be topics common to different themes. Hence, a conscious effort is needed to demonstrate the relationship between themes whenever possible.

Key Inquiry Questions in Diversity include:

- How do the diversity of things contribute to our lives?
- How do we classify things in our world?
- How do we find out the properties and characteristics of things around us?

Figure 7: Example of Key Inquiry Questions in the Syllabus

Essential Takeaways:

- The diversity of the rich resources in the natural world is important for the continual survival of living things.
- We have to use nature's resources responsibly and sustainably, e.g., applying the 3Rs (reduce, reuse, recycle).
- We continually seek to understand the complexity in the natural world by studying it in a systematic manner.

Figure 8: Examples of Essential Takeaways in the Syllabus

d. Learning Outcomes

The learning outcomes outline what we want our students to be able to do, as evidence of their learning of Core Ideas, development of Practices, and cultivation of the Values, Ethics and Attitudes.

The choice and scope of topics in the syllabus content are based on: (i) perspectives from teachers on the themes and topics; (ii) a consideration of students' prior knowledge from Primary Science and requisite knowledge for Upper Secondary Science; (iii) the subject matter of LSS as general science; and (iv) an understanding of the milieu (e.g. the development of scientific literacy for basic citizenry, an exposure to STEM learning, and instilling a joy of learning, entrepreneurial dare and the Singapore Heartbeat).

The learning outcomes in the G2/G3 LSS syllabuses have been arranged in three columns, namely "Core Ideas", "Practices" and "Values, Ethics and Attitudes".
The learning outcomes within the "Core Ideas" develop students' understanding of the Core Ideas of Science. The learning outcomes within the "Practices" column develop the ways of

thinking and doing in science and introduce students to the nature of science. The learning outcomes within the “Values, Ethics and Attitudes” column provide opportunities for students to model scientific values, ethics or attitudes by leveraging real-world contexts related to Science-Technology-Society-Environment (STSE) or stories that reflect the nature of scientific knowledge.

The learning outcomes under the three columns of “Core Ideas”, “Practices” and “Values, Ethics and Attitudes” are interrelated and together, represent a holistic understanding of science.

SECTION 3: PEDAGOGY

3. PEDAGOGY

3.1 Teaching and Learning of Science

The starting point for the science curriculum is that every child wants to and can learn. Hence, as part of our fraternity's education philosophy, we embrace the belief that all children are curious about and want to explore the things around them. The science curriculum leverages and seeks to fuel this spirit of curiosity. To nurture students as inquirers, teachers are key in facilitating a variety of learning experiences to support students in understanding Core Ideas, developing Practices and cultivating Values, Ethics and Attitudes. These experiences can be situated in authentic contexts in both formal and informal learning platforms. The experiences should inspire students to inquire and innovate.

3.2 Students as Inquirers

To nurture students as inquirers, they can be provided with learning experiences centred on authentic contexts that allow them to pose questions, be involved in discussions on socio-scientific issues, or be engaged in problem solving. Through these learning experiences, students are encouraged to:

- <u>ask questions as they engage with an event, phenomenon, problem or issue</u>. They ask questions which they are interested to find out. These questions 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 equipment. After the data collection, they present the evidence in appropriate forms (e.g. tables, charts, graphs) to facilitate the analysis of patterns and relationships.

- <u>formulate explanations based on the evidence gathered</u>. They explain using their own words, based on the evidence gathered (e.g. qualitative descriptions of observations or quantitative data collected over a time interval).

- <u>connect their explanations to various contexts</u>. They explain how the concepts are related or applied in various contexts around them. This helps them to appreciate how Science is relevant in everyday life.

- <u>communicate and justify their explanations</u>. They communicate using various types of representations. For example, they can use texts, drawings, charts, tables, graphs or a combination of representations to support their explanations.

- <u>reflect on their learning and progress</u>. 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 (**Figure 9**).

Figure 9: Examples of Blended Learning experiences

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

Table 4: Elaboration of possible Blended Learning experiences

3.4 Teachers as Facilitators

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

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

As facilitators, teachers should:

- provide students with opportunities to ask questions about events/ phenomenon/ problems/ issues that are related to their daily lives, society and environment;
- support students in gathering and using evidence;
- encourage students to formulate and communicate explanations based on evidence gathered;
- encourage students to apply concepts learnt in understanding daily events/ phenomenon, finding solutions to problems/ issues and creating products; and
- check on students' understanding to ascertain if learning has taken place and provide appropriate and meaningful feedback to address students' learning gaps.

The *Pedagogical Practices* in the *STP*, as shown in **Figure 10**, 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 primary to lower 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.

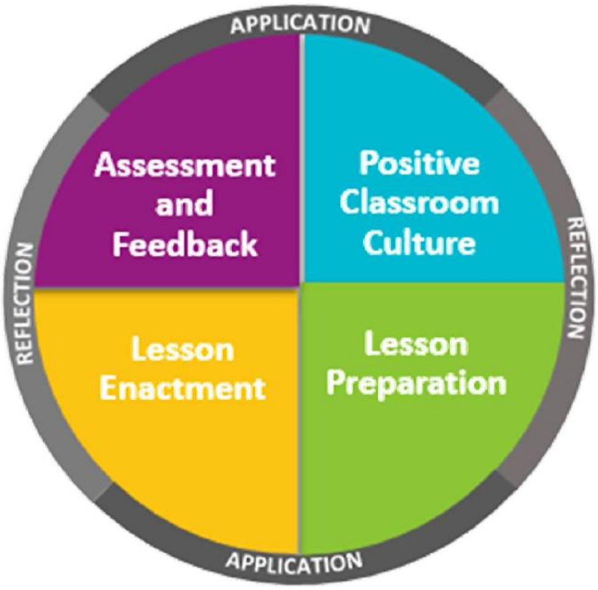

Figure 10: The four core *Teaching Processes* within the *Pedagogical Practices* in *STP*

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.

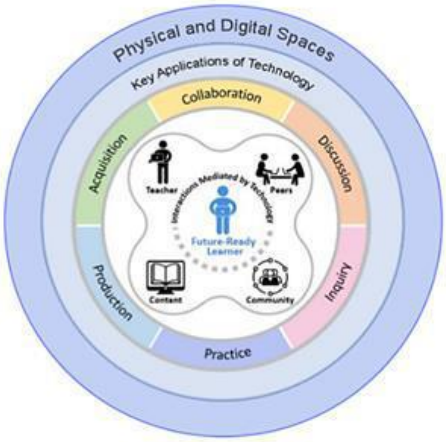

Figure 11: Overview of e-Pedagogy

Teachers can be guided by the Key Applications of Technology (**Figure 11**) 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

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

In the G2/G3 Lower Secondary Science syllabuses, students can be acquainted with the use of basic digital tools (e.g. data loggers, simulations etc). Apart from better preparing students for the technologically-driven world, using digital tools in the classroom supports the development of the practices of science. For instance, when students are given opportunities to collect experimental data using these tools, competencies such as understanding experimental design can be strengthened. Digital tools such as simulations or interactives allow students to explore and visualise abstract concepts better.

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 Singapore Student Learning Space (SLS), teachers should deploy a range of different response strategies in order to assess students' learning. Teachers can use the monitoring features to track students' learning progress, so as to provide timely feedback and interventions to close students' learning gaps.

3.6 Using Authentic Contexts to Support the Teaching and Learning of Science

Studies have shown that the use of context-based approaches in the teaching and learning of secondary school science motivate students in their science lessons and complement students' understanding of scientific ideas. In the G2/G3 LSS syllabuses, global issues related to Science-Technology-Society-Environment ('Sustainability', 'Climate Change', 'The Science Behind Healthcare', and 'Emerging Technologies') are used as contexts to lend currency and relevance to the themes. These issues are often encountered in daily experiences or phenomena locally or globally.

The function of contexts varies with the order of presentation of contexts and related concepts, for example:

- ***Contexts that are presented after concepts*** help to illustrate more abstract concepts taught and allow students to transfer and apply their conceptual understanding.

    - Activities in the Activity Books, such as the Practice Questions and the Integrative Activities, allow students to apply and transfer their knowledge from each topic or across topics to demonstrate their understanding of the theme and topics.

- ***Contexts that precede concepts*** provide rationale for teaching content and thus, orientate learning as well as enhance students' motivation in learning.

    - In the textbook, thematic opener and topic openers make use of authentic contexts to engage and orientate to make the learning of the themes and topics more meaningful and relatable for students. For practical activities in the activity book, each practical activity is prefaced and framed by these contexts to engage and orientate students in the applications of science and technology. These features are intended to use contexts to inspire students to make positive changes through the applications of their scientific knowledge.

The use of authentic contexts in LSS also provides opportunities for making connections between science knowledge and knowledge from other disciplines. This could help to reinforce students' learning in LSS, as well, as empower students in synthesizing their knowledge across subjects to understand and solve real-world problems.

3.7 Designing STEM Learning Experiences in Science

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

When designing STEM learning experiences, consider two aspects: 1) level of integration and 2) level of application. These two aspects lie on a continuum as illustrated in **Figure 12**.

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 12: Design considerations for STEM Learning

SECTION 4: ASSESSMENT

Purposes of Assessment
Obtaining Evidence of Learning

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 is 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**, 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.

- Assessment provides feedback to **teachers**, enables them to understand the strengths and weaknesses of their students. It provides information about students' attainment of learning outcomes as well as the effectiveness of their teaching.

- Assessment provides feedback to **schools**. The information gathered facilitates the placement of students in the appropriate stream or 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 Obtaining Evidence of Learning

The aims of the G2/G3 Lower Secondary Science are the acquisition of knowledge, understanding and application of science concepts, the ability to use process skills, and the development of attitudes important to Science. The assessment objectives of the syllabus are aligned to the three domains in the *Science Curriculum Framework*.

In an inquiry-based classroom, assessment can take many forms. In addition to written assessments, teachers can also conduct performance-based assessments, which may include:

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

The assessment modes listed above are by no means exhaustive. Adopting a variety of assessment modes enables teachers to assess different aspects of teaching and learning.

For meaningful assessment, teachers can use real-world contexts involving Science in daily life, society and the environment as the starting point for the construction of assessment tasks. This helps students to understand and appreciate the application of scientific knowledge in real-life contexts.

Assessment should be conducted constantly during classroom instruction to support teaching and learning. Information gathered from the assessment is used to adjust and improve the teacher's teaching practices, as well as surface students' learning progress and difficulties.

To summarise how much or how well students have achieved at appropriate checkpoints of a course of study, for example through end-of-year examinations, assessment should be designed to cover a representative sample of the syllabus, allowing students to make connections across what they have learnt in the course of the two years of study. The assessment content should well-represent the syllabus in terms of scope and relevance as well as be pitched at the appropriate difficulty level.

SECTION 5:
LEARNING OUTCOMES

5. LEARNING OUTCOMES

<table>
<tr><th colspan="3">A. THE SCIENTIFIC ENDEAVOUR</th></tr>
<tr><td>Thematic Overview</td><td>Theme: The Scientific Endeavour

What is “The Scientific Endeavour”?

The Scientific Endeavour helps us explore and understand the natural and physical world. It involves the acquisition of scientific knowledge partly through systematic observation, experimentation and analysis, and partly through human imagination and creativity. This scientific knowledge is reliable and durable but open to change in light of new evidence that is widely accepted within the scientific community[1].

Why is “The Scientific Endeavour” important?

It fosters the joy of learning Science by deepening the appreciation of the role of science in understanding everyday phenomena. By immersing in the practices and applications of science, we are empowered to inquire, make personal decisions, and improve our lives. The application of scientific knowledge can have beneficial or harmful consequences.

How does the Lower Secondary Science (LSS) curriculum bring out the essential takeaways of “The Scientific Endeavour”?

“The Scientific Endeavour” sets the foundation in understanding the topics in LSS. The study of the themes in LSS will reinforce the Core Ideas; Practices of Science; Values, Ethics, and Attitudes that characterise Scientific Endeavour.</td><td>Key Inquiry Questions in the Scientific Endeavour include:

• What is the nature of scientific knowledge?
• How do we practise Science?
• What influences the way we practise Science?
• Why do we learn Science?</td></tr>
</table>

[1] This is relevant to the Nature of Scientific Knowledge which is included under Practices of Science

Essential Takeaways	Learning Outcomes
SE 1: Science is a study of the natural phenomena in the world.	• show an awareness that Science is not confined to the laboratory, but is manifested in all aspects of our lives • show a healthy curiosity about the natural phenomena in the world
SE 2: Scientific knowledge is derived from cycles of systematic observation, experimentation and analysis and from human imagination and creativity. Scientific knowledge is subject to change.	• show an appreciation of Science being a human endeavour, with scientific knowledge contributed by different civilisations over the centuries • recognise that scientific evidence can be quantitative or qualitative, and can be gathered through one's senses or instruments as extensions of one's senses • show an understanding of how scientific knowledge is built from systematic collection, and analyses of evidence and rigorous reasoning based on the evidence • show an awareness that scientific evidence is subject to multiple interpretations • use scientific inquiry skills such as posing questions, planning, and carrying out investigations, evaluating experimental results and communicating *findings (Estimation and measurement skills, knowledge of SI units, and using appropriate units for the respective physical quantities, should be infused into the respective topics)* • show an understanding that accuracy refers to the closeness of agreement between a measured value and the true value of what is being measured • show an understanding that precision of measurement refers to the closeness of agreement between measured values obtained by repeated measurements • identify zero errors as the condition where the measuring instrument registers a reading when there should not be any reading • identify parallax error as an error in reading an instrument as a result of not viewing the measurement scale from the correct position • *show an understanding that measurement errors may exist due to errors that are either unpredictable (e.g., human error) and / or consistent (e.g., zero error of instrument) • show attitudes such as creativity, objectivity, integrity, open-mindedness, and perseverance in carrying out scientific inquiry • demonstrate safety consciousness and adopt safe practices when carrying out investigations
SE 3: Applications of Scientific knowledge can bring about beneficial or harmful consequences.	• discuss the beneficial and harmful consequences of scientific and technological applications to society • relate applications of Science to some social and ethical issues • state some current limitations of science and technology in solving societal problems • recognise the need to be responsible towards society and the environment in using technology and scientific knowledge

B. DIVERSITY

Theme: Diversity

What is "Diversity"?

There is a great variety of living and non-living things in the world. Classification helps us better understand the diversity of things in the world. Knowledge about the diversity of living and non-living things is reliable and durable. In light of new evidence that arises from technological advancements, this knowledge is open to change.

Why is the study of "Diversity" important?

In science, we make sense of the complexity in the diversity of things in the world by organising them based on the common characteristics. This helps us understand and appreciate the similarities and uniqueness in things. However, some phenomena may not fit neatly into pre-determined categories. In cases of such exceptions, critical debate within the scientific community helps to make a considered judgment, guided by a set of established procedures and practices. Hence, we are able to understand the world around us better and, in turn, are inspired and empowered to improve life.

How is an integrative experience for the theme like?

Building on what students learnt about the diversity of things in Primary Science, they will learn about the need to identify criteria for the different forms of matter.

Using the real-life context of sustainable living, students will appreciate and distinguish among the different physical properties and chemical composition of materials. They will then apply their understanding of materials through the use of various separation techniques.

Key Inquiry Questions in Diversity include:

- How does the diversity of things contribute to our lives?
- How do we classify things in our world?
- How do we find out the properties and characteristics of things around us?

Essential Takeaways:

- The diversity of the rich resources in the natural world is important for the continual survival of living things.
- We have to use nature's resources responsibly and sustainably, e.g., applying the 3Rs (reduce, reuse, recycle).
- We continually seek to understand the complexity in the natural world by studying it in a systematic manner.

2. Exploring Diversity of Matter by its Physical Properties Students will explore and learn about the different physical properties of materials. They learn to identify criteria for distinguishing characteristics that help them understand the world. This will also enable them to make informed decisions on the appropriate use of materials for everyday products/situations to increase efficiency, safety and sustainability.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• describe physical properties that can be observed or measured, e.g., - electrical conductivity - thermal conductivity - melting/ boiling point - *strength - *hardness - *flexibility - density • show an understanding of how mass and volume affect density	• classify a number of common everyday objects and recognise that there are many ways of classifying the same group of objects • evaluate the usage of different materials using data of their physical properties • communicate findings on classification and justify reasons • estimate length, mass and volume • measure accurately length, mass and volume (including mass and volume of liquids and solids but not of gases) of matter using appropriate instruments (measuring tape, metre rule, digital calipers, measuring cylinder, electronic balance) and methods. • *apply concepts of volume displacement to derive the volume of irregular objects • predict whether an object will sink or float by comparing its density with that of its surrounding medium • calculate density using the formula (density = mass/volume) and use the appropriate unit (e.g., g/cm^3 or kg/m^3)	• show an awareness of the importance of making informed choices of the appropriate and sustainable use of materials for household products (e.g., fibre, plastics, ceramics, metals and glass) based on their physical properties, (e.g., demonstrate curiosity about the physical properties of things commonly encountered in daily life) • show an appreciation of how reducing the use of non-sustainable materials by using alternative materials with similar properties helps to minimise environmental impact

** Optional for G2 Lower Secondary Science*

3. Exploring Diversity of Matter by its Chemical Composition Students will make inferences on the behaviours and characteristics of the variety of matter that are encountered in daily life, as they inquire into the chemical composition of matter. This helps them further classify matter beyond physical properties and enables them to make informed decisions about the appropriate use of matter, based on their chemical composition.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• state that elements are the basic building blocks of living and non-living matter • recognise that there are different types of elements represented in the Periodic Table of Elements, e.g., metals and non-metals • show an understanding that compounds are substances consisting of two or more chemically combined elements • show an understanding that compounds have different characteristics from their constituent elements • show an understanding that mixtures are made up of two or more elements and/or compounds that are not chemically combined • show an understanding that mixtures display characteristics of their constituents • distinguish between solute, solvent and solution • show an understanding that solutions and suspensions are mixtures • distinguish between elements, compounds and mixtures	• classify matter as elements, compounds and mixtures based on their chemical composition • investigate the factors that affect the rate of dissolving and *solubility of substances	• show an appreciation of how recycling and reuse of precious materials can be facilitated by the classification of waste products based on their chemical composition • show an awareness of the importance of knowing the chemical composition of everyday items and how it can be beneficial (e.g., melamine used for making plastic containers) or harmful (e.g., melamine in milk powder)

** Optional for G2 Lower Secondary Science*

4. Exploring Diversity of Matter using Separation Techniques Students will apply their understanding of the diversity in the physical properties and chemical composition of matter to decide on the appropriate separation techniques in order to obtain different constituents to aid in reusing and recycling resources.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• explain how the constituents of a mixture can be separated based on their properties, using the following techniques: - magnetic attraction, - filtration, - evaporation, - distillation, - paper chromatography • state some examples of the applications of the various separation techniques in everyday life and industries e.g., water treatment (i.e. distillation or *reverse osmosis of sea water in desalination plants, and filtration and *reverse osmosis of treated used water), food safety and waste management	• investigate the separation of constituents of mixtures based on basic principles involved in the following separation techniques: - magnetic attraction, - filtration, - evaporation, - distillation, - paper chromatography	• show an appreciation of why water is a precious resource and the need to conserve it • show an appreciation of how Singapore uses separation techniques to ensure a sustainable source of potable water

** Optional for G2 Lower Secondary Science*

<table>
<tr><th colspan="2">C. MODELS</th></tr>
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Theme: Models

What is "Models"?

Models are physical, conceptual or mathematical representations of phenomena. As models are approximations of actual phenomena, they are inherently inexact and can be improved upon.

Why is the study of "Models" important?

Processes and structures in the world can be abstract or invisible to the naked eye. As they cannot be observed directly, we can construct models as representations to understand the world. These models are developed or modified based on evidence. They can help us develop explanations and make reasonable predictions of the phenomena. Models of phenomena change as Man improves his understanding of phenomena, due to technological advancements and the discovery of new evidence. The new knowledge contributes to advancement in science and technology, which in turn has the propensity to improve life around us.

How is an integrative experience for the theme like?

I.E.

Students will be introduced to the role of scientific models to represent things that are abstract (e.g., the ray model of light and the particulate nature of matter), or invisible to the naked eye (e.g., model of cells; models of atoms and molecules). Students will get a chance to see how the practice of using and constructing models in the topics they learn today relate to emerging technology and appreciate the uses and benefits of technology. Furthermore, students will use these models to investigate possibility of supporting life on Mars and learn about the usefulness and limitations of models.

</td>
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Key Inquiry questions in Models include:

- Why is the construction and use of models important?
- How do we know that the models used are appropriate representations of the real phenomena?

Essential Takeaways:

- Models are simplified representations of phenomena that provide a physical, conceptual or mathematical perception of reality.
- Models are constructed to explain phenomena.
- Models can be used to make predictions.

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5: Ray Model of Light

Students will learn how the ray model of light is used to represent the pathway of light rays and use this model to learn about reflection, refraction and their applications in daily life.

<table>
<tr><th colspan="3">Learning Outcomes</th></tr>
<tr><th>Core Ideas</th><th>Practices</th><th>Values, Ethics, and Attitudes</th></tr>
<tr><td>• show an understanding that the ray model represents the path taken by light
• describe the effects and uses of reflecting surfaces (e.g., plane and curved)
• explain how reflection is affected by a smooth and rough surface using the ray model of light
• *show an understanding that the change in the speed of light in different mediums can cause refraction (calculation of angles not required)
• *describe some effects of refraction
• *describe the dispersion of white light by a prism using the ray model of light</td><td>• investigate the characteristics of the image formed by a plane mirror
• *investigate that the angle of reflection is equal to the angle of incidence, with respect to the normal</td><td>• show an awareness that EM radiation (e.g., infrared, ultraviolet and light) has both beneficial and harmful effects. (Note: abbreviation, “EM”, suffice; spelling of the full word “electromagnetic” is not required)
• show an awareness about the impact of light produced by technology, on society and environment (e.g., city lights can improve night visibility but cause light pollution, disorientation of birds and use up a lot of electrical energy)</td></tr>
</table>

** Optional for G2 Lower Secondary Science*

6: Model of Cells – the Basic Unit of Life

Students will learn about a typical plant cell and a typical animal cell as models and how this knowledge can be used to predict behaviours and functions of cells.

Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• show an understanding of the functions of the different parts of a typical cell, including the nucleus which contains genetic material (DNA) that can be passed down to the next generation. (Note: *the abbreviation DNA will suffice; spelling of the full word and structure of DNA is not required*) • show an understanding that typical plant and animal cells are models used to represent their various forms • recognise that in multicellular organisms (e.g., plants and animals), cells are the basic building blocks that are organised into tissues, organs and systems • *explain the significance of the division of labour even at the cellular level	• identify, *using the microscope safely and correctly, the different parts of a typical cell (plant or animal): - cell wall - cell membrane - cytoplasm - nucleus - vacuole - chloroplast • infer whether an organism is an animal or a plant, based on its cell structures	• show an appreciation for the relationship between advances in technology and knowledge-building, e.g., the development of the microscope

** Optional for G2 Lower Secondary Science*

7: Model of Matter – The Particulate Nature of Matter Students will use the particulate nature of matter as a model to explain the properties of the different states of matter and their behaviours upon heating or cooling. The understanding of the particulate nature of matter as a model will help students better appreciate phenomena like diffusion.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• show an awareness about the particulate nature of matter being a model representing matter that is made up of small discrete particles in constant and random motion • describe the arrangement and movement of the particles in matter in the solid, liquid and gaseous states using the particulate nature of matter • show an understanding that diffusion is the net movement of particles from a region of higher concentration (i.e., more solute particles per unit volume of the solution) to a region of lower concentration (i.e., fewer solute particles per unit volume of the solution)	• explain expansion and contraction, and the conservation of mass during these processes, using models • *explain melting and boiling in terms of the conversion of three states of matter, using models	• show an appreciation of scientific attitudes such as creativity and open-mindedness in creating models to explain the fundamental nature of things, and the willingness to re-examine existing models e.g., attitudes required to derive the particulate nature of matter (Brownian Motion)

** Optional for G2 Lower Secondary Science*

8: Model of Matter – Atoms and Molecules Students will be introduced to the world of atoms and molecules. The atomic model facilitates the understanding of atomic structure which cannot be observed with the naked eye.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• describe an atom as an entity that is electrically neutral and is made up of a positively charged nucleus (protons and neutrons) with negatively charged electrons moving around the nucleus • *recognise that atoms have mass that is mainly contributed by the mass of the nucleus • show an awareness that the atoms of an element have a unique number of protons • show an understanding that a molecule is a group of two or more atoms that are chemically combined • state the numbers and types of atoms, given the chemical symbol of an element or the chemical formula of a compound, e.g., carbon dioxide (Note: *Writing of chemical formulae is not required. Giant molecular compounds are also not required.*)	• compare the size of an atom with the sizes of everyday objects • compare atoms and molecules	• *show an appreciation of how, in practice, models are constructed, justified and continuously revised as they are used to probe new phenomena and collect additional data (e.g., the various atomic models) • show an awareness that technologies resulting from the knowledge of atoms have created social and ethical issues, risks and costs (e.g., atomic bombs)

** Optional for G2 Lower Secondary Science*

D. INTERACTIONS

Theme: Interactions

What is "Interactions"?

Interactions in Science refer to the relationships among the different forms of matter and the effect they have on each other. Changes as a result of interactions are brought about by the transfer of energy between matter. These may lead to changes in motion, which can be fast or slow as well as changes in conditions, which can be big or small, reversible or irreversible. Such interactions may increase or decrease the stability within a system.

Why is the study of "Interactions" important?

Analysis of interactions can reveal patterns in nature that help us to predict how changes in one factor affect other factors in a system or among systems. This knowledge helps us to design solutions and make more informed decisions in our daily lives as there are risks and benefits associated with the applications of Science in society.

How is an integrative experience for the theme like?

Students will learn about how interactions with our environment (e.g., combustion of fuel may relate to climate change). Such changes in the environment, in turn, may intensify natural disasters (a context which comprises the application of forces) and cause chemical changes which can affect the ecosystem. They will also appreciate that all these changes are brought about by the transfer of energy, as a result of interactions. This helps students to appreciate how Singapore is adapting to cope with climate change and explore how we, as individuals can do our part to mitigate climate change.

Key Inquiry Questions in Interactions include:

- How does knowledge of interactions between and within systems help us better understand and improve our environment?
- What are the examples of interactions between physical phenomena and life processes?

Essential Takeaways:

- Interactions usually involve the transfer of energy which can cause changes in motion and/or conditions.
- Our interactions with the world can lead to changes which influence the stability of a system. Thus, we must make responsible choices in our daily lives.
- Our interactions with the environment drive the development of science and technology. At the same time, science and technology influences the way we interact with the environment.

9: Application of Forces and Transfer of Energy Students will discover the effects of forces in the interactions that they encounter in their everyday lives, bringing about transfer of energy. They will also learn how choices of energy sources affect the environment.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• show an understanding that a force can be a contact force (e.g., friction) or non-contact force, (e.g., magnetic force, gravitational force) • recognise that the interactions between two or more objects result in a transfer of energy which can/may cause changes (by application of force) to the: - state of rest or motion of an object - turning effects in objects (e.g., spanners, levers to open tins) - size and/or shape of an object - pressure on objects • *show an appreciation of some daily life phenomena associated with: - pressure (e.g., high-heeled shoes, cutting edge of a knife) - atmospheric pressure (e.g., use of suction cups, drinking from straws) - pressure due to liquid (e.g., submarines have depth limits) • state the SI unit of *work and energy as the joule • *identify that work is done is an example of energy transfer that occurs when an object moves in the direction of a force	• measure force, using newton as the SI unit • compare weight and mass • *investigate pressure using the formula, pressure = force/area • infer that energy can be converted from one form to another	• show curiosity about the destructive power of forces in nature (e.g., earthquakes, tsunamis, volcanic eruptions, tropical cyclones) • show an appreciation of the uses of various sources of energy (e.g., fossil fuels, solar energy, hydroelectric energy, wind energy, geothermal energy, biofuels and nuclear energy) and their impact on the environment

• recognise that energy cannot be created or destroyed, and is conserved when it is transferred (from one object to another) and/or converted from one form to another		

** Optional for G2 Lower Secondary Science*

10: Transfer of Heat Energy and its Effects Students will learn about how the transfer of heat energy occurs, the changes that are brought about by the transfer of heat energy as well as the applications of such effects of heat transfer in our daily lives.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• state that the SI unit of temperature is kelvin (K) • describe some effects and applications of expansion and contraction in everyday life • explain the transfer of heat energy through conduction, convection, and radiation • show an understanding that the rate of heat energy loss or gain by a body through radiation is affected by the (i) colour and texture of the surface (ii) surface temperature • explain applications of transfer of heat energy through conduction and convection (e.g., in cooling, heating and insulation) • explain applications of transfer of heat energy through radiation (e.g., radiant heaters, solar radiation)	• infer that generally, solids, liquids, and gases expand when heat energy is absorbed and contract when heat energy is given out • infer that thermal expansion results in a change in volume, and therefore the density of the substance • infer from experiments that different materials have different rates of heat energy transfer	• show an awareness of the various proposed causes (man-made and natural) of climate change (e.g., global warming)

** Optional for G2 Lower Secondary Science*

11. Chemical Changes

Students will explore the chemical changes that matter can undergo when interacting with each other. They will also learn how chemical reactions can be beneficial and harmful to our daily lives and the environment.

Learning Outcomes

Core Ideas	Practices	Values, Ethics, and Attitudes
• identify a change that leads to the formation of new substance(s) as a chemical change • use word equations to represent chemical reactions (Note: Chemical equations are not required.) • recognise that chemical reactions involve a rearrangement of atoms which are not created or destroyed • recognise that mass is conserved during a chemical reaction • show an awareness that there are different types of chemical changes such as combustion, thermal decomposition, oxidation (e.g., rusting and cellular respiration) and neutralisation	• investigate the chemical reactions between: - acids and alkalis; - *acids and metals; and - *acids and carbonates • investigate the effect of acidic, alkaline and neutral solutions on indicators (include litmus paper, Universal Indicator and natural indicators obtained from plants) • investigate the chemical changes that matter (i.e., element, compound or mixture) undergoes upon: - mixing (e.g., neutralisation) - heating (e.g., thermal decomposition) - exposure to light (e.g., photosynthesis) - interacting with oxygen (e.g., rusting and cellular respiration) - *using an electric current (e.g., electroplating) (Note: Electroplating is stated as an example which may be used for students to observe visual changes. Knowledge of the anode, cathode and reactivity series of metals are not required.)	• show an awareness of how chemical reactions can benefit our lives (e.g., cooking, respiration) and cause harm to our health and environment (e.g., rusting, decay, burning)

** Optional for G2 Lower Secondary Science*

12: Interactions within Ecosystems

Students will explore the interaction of living things with both the biotic (living) and abiotic (non-living) factors in the ecosystem. They will also learn about how climate change can affect ecosystems and what we can do to maintain biodiversity.

Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• explain the importance of conserving the environment • explain the importance of various physical factors such as air, water, temperature, light, minerals and acidity/alkalinity to the survival of organisms • recognise how adaptive traits (structural and behavioural) and changes in environmental conditions can affect the survival of organisms • show an understanding of an ecosystem as the interactions between a community and its physical environment • show an understanding of the interrelationships between various organisms in a community (e.g., predator-prey relationship, mutualism and parasitism) • show an understanding that energy flows through food chains and food webs and how processes such as photosynthesis and respiration are involved. • *describe how nutrients in organisms are recycled within the environment through the action of decomposers	• *investigate an environment using measuring instruments such as a data logger and probes to collect data on physical factors such as pH, temperature and light intensity	• evaluate the impact of human activities and technology on the environment (e.g., motor vehicles and modern lifestyle) • *show an awareness of how some cultures practise sustainable living through their interactions with the environment

** Optional for G2 Lower Secondary Science*

<table>
<tr><th colspan="2">E. SYSTEMS</th></tr>
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Theme: Systems

What is "Systems"?

A system is defined by placing boundaries around inter-related entities. The behaviours and functions of systems can be understood through observation and measurement. This knowledge about a system is supported by the assumption that processes and structures in systems behave in a consistent manner.

Why is the study of "Systems" important?

Any change to a part of the system could affect the rest of the system to different extents. That is, a part of the system may not work (well) if another part is missing or not working (well). Conversely, when the parts are put together, they can perform functions that cannot be carried out by individual parts. By conducting scientific investigations, we can construct and test explanations to discover how parts of a system affect one another and learn about the structures and functions of these parts. This also allows us to develop and test solutions for problems in natural systems.

How is an integrative experience for the theme like?

Students will explore how the different components in the <u>digestive</u>, <u>transport</u> and <u>sexual reproductive systems</u> in humans work together. In cases of disruption of the systems, diseases like diabetes, heart attack or infertility may occur. Through exploring <u>electrical systems</u>, students will also consider the impact of science and technology on helping to detect, treat or alleviate the symptoms of such diseases. In the process, students will gain deeper insights into how lifestyle choices can affect their health.
</td>
<td>
Key Inquiry Questions in Systems include:

• How do parts of a system or different systems work together to perform a function?
• How could parts of a system affect the function of other parts?
• How may a system be affected when a part or parts of the system do not behave in a consistent manner and what can be done to make these parts behave in a consistent manner?

Essential Takeaways:

• A system is a whole consisting of parts that work together to perform a function.
• Each part of a system performs a specific function that contributes to the overall function of the system.
• The functions of a system may be disrupted if a part or parts of the system do not function well.
</td>
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</table>

13: Electrical Systems Students will explore man-made electrical systems and appreciate the electrical components that make up an electrical system.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• describe current, potential difference, and resistance of an electrical system, stating their SI units • describe the applications of the chemical, heating and magnetic effects of an electric current • state how changes made to an electrical system can cause some electrical hazards • state some precautionary measures to ensure the safe use of electrical energy in households • explain what is meant by power, relate it to an output of an electrical system, and state its SI unit	• draw and interpret circuit diagrams and set up circuits containing electrical sources, switches, lamps, resistors (fixed and variable), ammeters and voltmeters • *investigate how the series or parallel arrangement of fixed resistors affects the current as an output of an electrical system • *investigate the effect of varying resistance on the current in the circuit using fixed or variable resistors (Note: formula V=IR is not required) • *calculate the cost of using electrical appliances, using kilowatt-hour as a unit of electrical energy consumption	• show an awareness of the ways to reduce the consumption of electrical energy in households

** Optional for G2 Lower Secondary Science*

14. Human Digestive System Students learn about the primary role and function of the human digestive system. They will understand how different parts of the system work together to carry out digestion. They will explore how the malfunction of one part affects the system and learn how the end-products of the human digestive system are used for life processes.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• explain the importance of the digestive system • explain how the main parts of the human digestive system (e.g., mouth, gullet, stomach, small intestine, large intestine, rectum and anus) work together to perform a function • describe how a human digestive system helps in the digestion of food • *state that the end products of digestion are used for cellular processes like respiration, growth and tissue repair	• *investigate the effect of enzymes in digestion (Note: *Only classes of enzymes such as carbohydrases, proteases and lipases are needed. Specific names of enzymes are not required.*)	• show an appreciation of the importance of sensible food and lifestyle choices in the fight against diabetes • show an awareness that bacteria could have beneficial or harmful effects (e.g., bacteria in the digestive tract could help in digestion or cause infections)

** Optional for G2 Lower Secondary Science*

15. Transport Systems in Living Things

Students learn about the primary roles and functions of the transport systems in plants and human beings. They will understand how different parts of the transport system work together to perform its function. Students then go on to explore how the malfunction of one part affects the transport system.

Learning Outcomes

Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• describe the functions of blood vessels in relation to the transport system in humans: - arteries (carry blood away from the heart) - veins (carry blood towards the heart) and - capillaries (the site of exchange of substances) (Note: Structures of the blood vessels and the heart are not required.) • *show an understanding that the xylem transports water and mineral salts from the roots to other parts of the plant while the phloem transports food from the leaves to other parts of the plant • *explain the need for a transport system in multi-cellular organisms • explain how diffusion facilitates the transport of substances in humans (e.g., diffusion of digested food and oxygen from blood to tissues) • explain how diffusion facilitates the transport of substances in plants (e.g., diffusion of gases and mineral salts into and out of plant cells) • *state that osmosis facilitates the absorption of water at the roots	• *infer from investigation that the xylem transports water and mineral salts	• show an awareness that the abuse of drugs has detrimental effects on many systems in humans, including the transport system • show awareness of the ethical issues relating to heart transplant (e.g., donor consent and priority for allocation)

** Optional for G2 Lower Secondary Science*

16. Human Sexual Reproductive System Students learn about the primary role and function of the human sexual reproductive system is for reproduction. They will understand how different parts of the reproductive system work together to perform its function. They also explore how the disruption of one part affects the function of the system.		
Learning Outcomes		
Core Ideas	**Practices**	**Values, Ethics, and Attitudes**
• recognise that the union of the nuclei of an egg and a sperm (inputs of a system) forms a fertilised egg which develops into a new individual (output of a system) • recognise that the sexual reproductive system facilitates heredity (the passing down of genetic material from one generation to the next) • *recognise that a new individual formed through sexual reproduction receives a unique combination of genetic information from the mother (via the egg) and the father (via the sperm), resulting in similarities and differences between individuals and their parents, as well as among siblings • state some of the physical changes that occur during puberty and early adolescence as a result of the effect of hormones on other systems (Note: D*etails of the hormonal system are not required*) • describe briefly how the parts of the human male and female reproductive systems are involved in fertilisation • describe how parts of the female reproductive system are involved in the menstrual cycle	• evaluate the consequences and issues relating to abortion and pre-marital sex	• show an awareness that substance abuse (e.g., smoking, alcohol consumption and drug abuse) can have negative effects on the foetus • *suggest reasons for the world's growing human population (e.g., advances in medicine, improved sanitation)

• outline how temporary and permanent birth control methods prevent conception by disrupting certain processes and/or the functions of certain organs in the reproductive system • state the harmful consequences of sexually transmitted infections (STIs) like syphilis, gonorrhoea and AIDS • state that some bacterial STIs can be cured by antibiotics, but not viral STIs		

** Optional for G2 Lower Secondary Science*

SECTION 6:
GLOSSARY OF TERMS

6. GLOSSARY OF TERMS

This glossary serves as a guide for interpreting learning outcomes that are stated in this syllabus.

S/No	Term	Description of Terms
1	calculate	to give a numerical answer, where, in general working should be shown (especially when two or more steps are involved)
2	classify	to group things based on common characteristics
3	compare	to identify similarities and differences between things or concepts
4	construct	to write or form something not by factual recall but analogy or by using given information
5	describe	to state in words (using diagrams where appropriate) the main points of a topic
6	discuss	to give a critical account of the points involved in the topics
7	estimate	to make a reasoned order magnitude statement/calculation for the quantity concerned, making such simple assumptions as may be necessary about the points of principle and about values of quantities not otherwise included.
8	distinguish	to identify and understand the differences between objects, concepts and processes
9	evaluate	to consider all factors relating to the object/event before making a judgement
10	explain	to give reasons or make some reference to theory, depending on the context
11	identify	to select and/or name the object, event, concept or process
12	infer	to draw a conclusion based on observations
13	investigate	to find out by carrying out experiments
14	list	to give a number of points or items without elaboration
15	measure	to obtain the quantity concerned directly from a suitable measuring instrument
16	outline	to give the main or essential points of the concepts or processes
17	predict	to state a likely future event based on the given information or rules
18	recognise	to identify facts, characteristics or concepts that are critical (relevant/appropriate) to the understanding of a situation, event, process or phenomenon
19	relate	to identify and explain the relationships between objects, concepts or processes
20	show an appreciation	to recognise and explain the importance of a concept or situation
21	show an awareness	to show concern and perception in a particular situation or development
22	show an understanding	to recall, explain and apply information
23	state	to give a concise answer with little or no supporting argument

Section 7: Acknowledgement

7. ACKNOWLEDGEMENT

Members of the Lower Secondary Science E/N(A) Syllabus Resource and Development Committee (2016-2020) are:

Name	Designation
Sin Kim Ho (Mr) (up to 2017)	Divisional Director, Curriculum Planning and Development Division 1
Chua Chor Huat (Mr) (2018- 2019)	Director, Sciences, Curriculum Planning and Development Division 1
Chia Guo Hao (Mr) (up to 2017)	Senior Assistant Director, Sciences, Curriculum Planning and Development Division 1
Chua Shi Qian (Ms) (from 2018)	Senior Assistant Director, Sciences, Curriculum Planning and Development Division 1
Chin Tan Ying (Dr)	Assistant Director General Science/Master Specialist, Curriculum Planning and Development Division 1
Paul Chua (Dr) (up to 2019)	Principal/ Special Projects, Sciences, Curriculum Planning and Development Division 1
Anna Koh (Ms)	Master Teacher, Biology, Standards and Research Branch, Academy of Singapore Teachers
Md Shahrin (Dr)	Master Teacher, Chemistry, Standards and Research Branch, Academy of Singapore Teachers
Lau Chor Yam (Mr)	Master Teacher, Physics, Standards and Research Branch, Academy of Singapore Teachers
A/P Lee Yew Jin (Dr) (up to 2017)	Associate Professor, Natural Sciences and Science Education, National Institute of Education Singapore
Ong Kia Siang (Mr) (from 2018)	Teaching Fellow, Natural Sciences and Science Education, National Institute of Education Singapore
Tan Mui Hua (Dr)	Curriculum Specialist, STEM Inc, Science Centre Singapore
Yip Sun Yee (Ms) (up to 2017)	Vice-Principal, Fuhua Secondary School
Wesley Cheong Lit Sern (Mr) (up to 2017)	Vice-Principal, Yuan Ching Secondary School
Alvin Chen Jingyuan (Mr)	Head of Department, Educational Technology, Ngee Ann Secondary School
Tan Chiew Seng (Mr) (up to 2017)	Subject Head, Science, St. Patrick's School
Desmond Tan Sam Sheng (Mr)	Level Head, Lower Secondary Science, Kuo Chuan Presbyterian Secondary School
Teo Jo Hsuan (Ms)	Lower Secondary Science Coordinator, Chung Cheng High School (Main)
Chia Ai Li, Joan (Ms)	Lower Secondary Science Teacher, Evergreen Secondary School
Grace Khoo (Ms) (up to 2017)	Lower Secondary Science Teacher, NUS High School
Muhammad Hafiz Mornin (Mr)	Lower Secondary Science Teacher, Yishun Secondary School
Tan Hong Kim (Dr)	Lead Curriculum Resource Development Specialist (Science) , Curriculum Planning and Development Division 1
Phuan Siew Khoon (Ms)	Lead Specialist, Gifted Education, Curriculum Planning and Development Division 1
Liew Poh Yin (Mdm) (up to 2019)	Lead Specialist (Science), Curriculum Planning and Development Division 1
Charlene Seah Xinyi (Mdm)	Senior Curriculum Specialist (Lower Secondary Science), Curriculum Planning and Development Division 1

Wong Po San (Ms) (from 2019)	Senior Curriculum Specialist, Primary Science, Curriculum Planning and Development Division 1
Tay Wee Beng (Ms) (from 2020)	Senior Curriculum Specialist, Biology, Curriculum Planning and Development Division 1
Ang Keng Kiat (Mr) (up to 2017)	Senior Curriculum Planning Officer, Physics, Curriculum Planning and Development Division 1
Jennifer Teo Ie Bwen (Mdm) (from 2018)	Senior Curriculum Planning Officer, Lower Secondary Science, Curriculum Planning and Development Division 1
Chan Yan Qing Daphne (Mdm) (from 2019)	Senior Curriculum Planning Officer, Lower Secondary Science, Curriculum Planning and Development Division 1
Terence Ong Kian Wan (Mr) (2017 to 2019)	Senior Curriculum Resource Development Officer, Lower Secondary Science, Curriculum Planning and Development Division 1
Qiu Yiru (Ms) (up to 2018)	Education Technology Officer, Technologies for Learning Branch
Ang Xiu Qin (Ms) (from 2019)	Education Technology Officer, Technologies for Learning Branch
Serwin Leong (Mr) (up to 2019)	Curriculum Planning Officer, Chemistry, Curriculum Planning and Development Division 1
Grace Huang (Ms) (up to 2018)	Curriculum Planning Officer, Biology, Curriculum Planning and Development Division 1
Gerlynn Yap (Ms) (2019)	Curriculum Planning Officer, Biology, Curriculum Planning and Development Division 1
Amy Lui (Ms) (from 2019)	Curriculum Planning Officer, Chemistry, Curriculum Planning and Development Division 1
Kee Zhiyin (Ms) (from 2019)	Curriculum Planning Officer, Physics, Curriculum Planning and Development Division 1
Miko Tan (Mdm) (2016 – 2018)	Curriculum Resource Development Officer, Physics, Curriculum Planning and Development Division 1
Jacklyn Kong (Mdm) (2017 - 2018)	Curriculum Resource Development Officer, Lower Secondary Science, Curriculum Planning and Development Division 1
Tong Shuqing (Ms) (from 2018)	Curriculum Resource Development Officer, Lower Secondary Science, Curriculum Planning and Development Division 1
Quek Shir Ryn (Mdm) (from 2019)	Curriculum Resource Development Officer, Lower Secondary Science, Curriculum Planning and Development Division 1
Jamie Tay (Ms) (from 2020)	Curriculum Resource Development Officer, Lower Secondary Science, Curriculum Planning and Development Division 1

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