Science

Syllabus

Lower and Upper Secondary

Normal (Technical) Course

Implementation starting with
2014 Secondary One and Three Cohort

Ministry of Education
SINGAPORE

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CONTENTS

PREAMBLE

This Secondary Science Normal (Technical) Syllabus is a four-year course that has been designed to equip Secondary school students in the Normal (Technical) course with the foundation in Science for post-secondary courses.

This syllabus is based on the *Science Curriculum Framework* and emphasises the need for a balance between the acquisition of science knowledge, skills and attitudes. These have a direct bearing on the daily lives of the students, and are drawn equally from the physical, chemical and biological sciences.

The aims spelt out in the syllabus provide the guiding principles for the suggested teaching approaches and evaluation methods.

When implementing the syllabus, teachers should consider the learning ability and interest of their students and employ teaching approaches that make learning of science meaningful and engaging to them. This includes the use of ICT, both for pedagogical and formative assessment purpose, to enrich and deepen students' learning. Teachers can also consider using ideas and materials from various sources to enhance the learning of science.

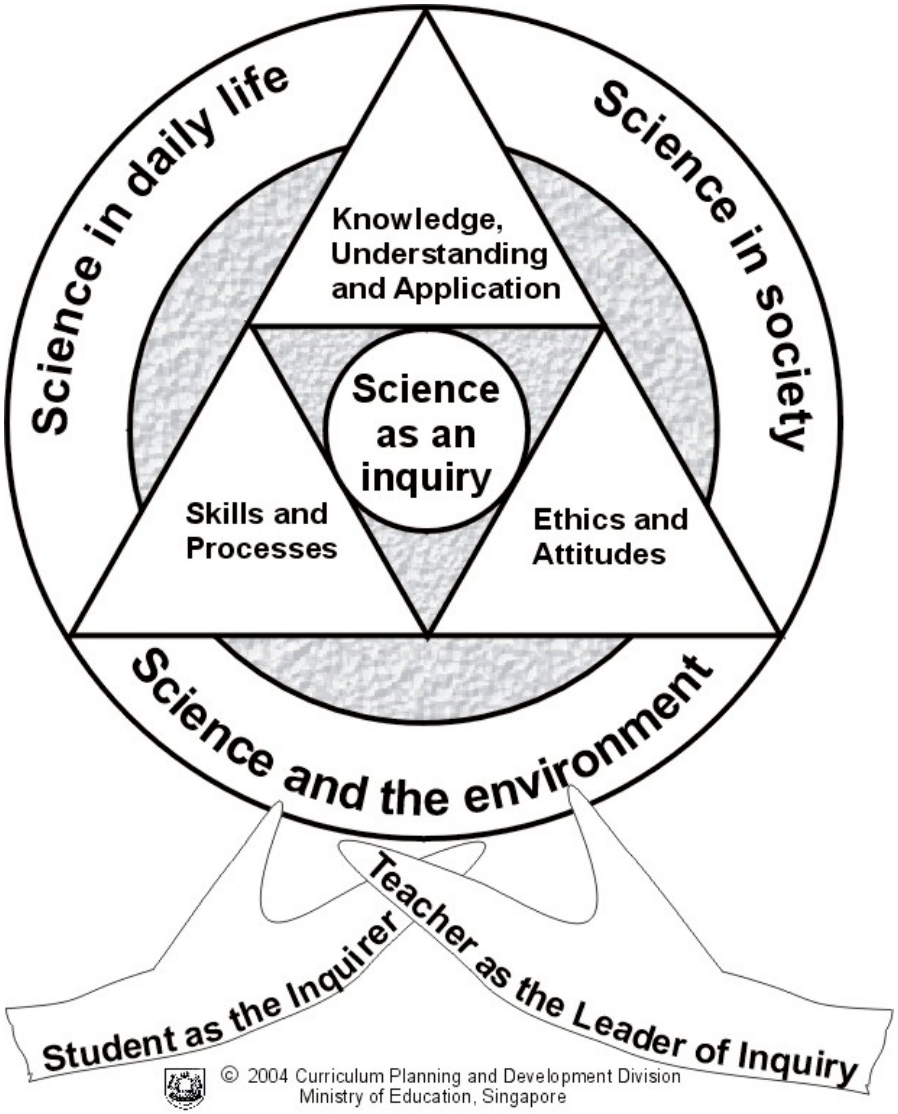
1 Overview

SCIENCE CURRICULUM FRAMEWORK

The *Science Curriculum Framework* is derived from the *Policy Framework for the Teaching and Learning of Science*. It encapsulates the thrust of science education in Singapore to prepare our students to be sufficiently adept as effective citizens, able to function in and contribute to an increasingly technologically-driven world.

Central to the curriculum framework is the inculcation of the spirit of scientific inquiry. The conduct of inquiry is founded on three integral domains of (a) Knowledge, Understanding and Application, (b) Skills and Processes and (c) Ethics and Attitudes. These domains are essential to the practice of science. The curriculum design seeks to enable students to view the pursuit of science as meaningful and useful. Inquiry is thus grounded in knowledge, issues and questions that relate to the roles played by science in daily life, society and the environment.

The science curriculum seeks to nurture the student as an inquirer. The starting point is that children are curious about and want to explore the things around them. The science curriculum leverages on and seeks to fuel this spirit of curiosity. The end goal is students who enjoy science and value science as an important tool in helping them explore their natural and physical world.



The teacher is the leader of inquiry in the science classroom. Teachers of science impart the excitement and value of science to their students. They are facilitators and role models of the inquiry process in the classrooms. The teacher creates a learning environment that will encourage and challenge students to develop their sense of inquiry. Teaching and learning approaches centre on the student as an inquirer.

The following table shows the description of each domain which frames the practice of science:

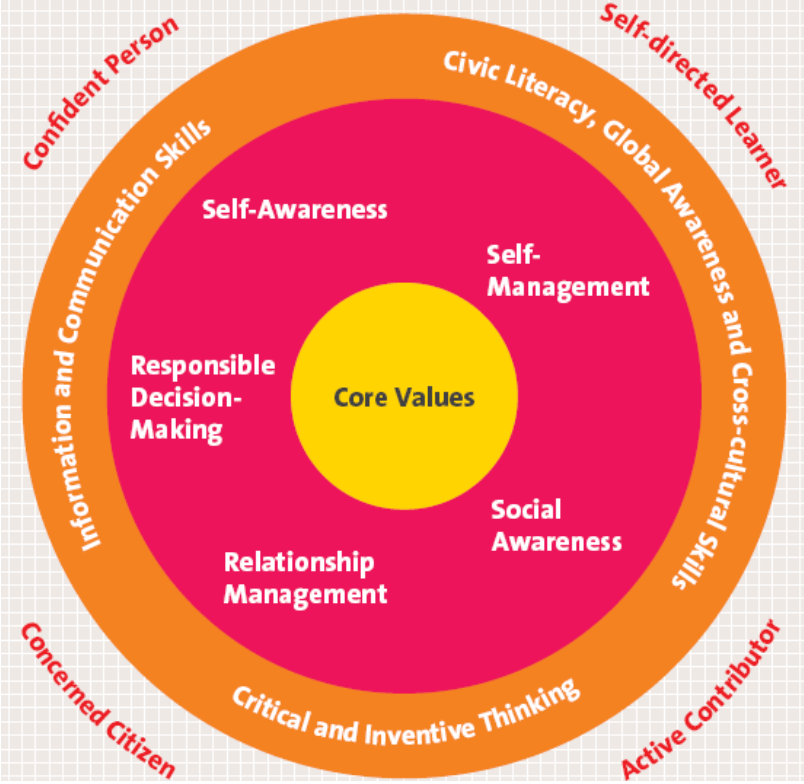
Knowledge, Understanding and Application of	**Skills and Processes**	**Ethics and Attitudes**
• Scientific phenomena, facts, concepts and principles • Scientific vocabulary, terminology and conventions (including symbols, quantities and units) • Scientific instruments and apparatus including techniques of operation and aspects of safety • Scientific quantities and their determinations	Skills • Posing questions • Formulating hypothesis • Defining the problem • Generating possibilities • Predicting • Observing • Using apparatus and equipment • Comparing • Classifying • Inferring • Analysing • Elaborating • Verifying • Communicating Processes • Creative problem solving • Planning investigation • Decision-making	• Curiosity • Creativity • Objectivity • Integrity • Open-mindedness • Perseverance • Responsibility

The domains are contextually linked to the roles played by science to establish its relevance and relationship to modern-day living:

Science in daily life - Personal perspective focusing on the individual	**Science in society** - Social perspective focusing on human interactions	**Science and the environment** - Naturalistic perspective focusing on man-nature relationship
• Showing curiosity, interest and enjoyment in science • Applying scientific concepts and skills to daily life • Making informed decisions that are related to the social, environmental, economic and technological aspects of science, e.g. lifestyle choices that affect personal health	• Becoming confident, responsible and productive citizens in a technological world • Showing awareness of science and technology on society, industry, business, home and leisure, e.g. sensitivity to the benefits and abuses of the applications of science	• Demonstrating safety consciousness and safe practices, e.g. when using apparatus and equipment • Showing care and concern for the environment, e.g. importance of conserving energy, reducing pollution

21ST CENTURY COMPETENCIES FRAMEWORK

The *21st Century Competencies Framework* encapsulates the thrust of education for the future, to prepare our students to be confident people, self-directed learners, concerned citizens, and active contributors – outcomes of individuals able to thrive in and contribute to a world where change is the only constant.



Core to the development of 21st century competencies are the values of respect, responsibility, integrity, care, resilience, and harmony.

Respect
A person demonstrates respect when he believes in his own self-worth and the intrinsic worth of all people.

Responsibility
A person who is responsible recognises that he has a duty to himself, his family, community, nation and the world, and fulfils his responsibilities with love and commitment.

Integrity
A person of integrity upholds ethical principles and has the moral courage to stand up for what is right.

Care
A person who is caring acts with kindness and compassion. He contributes to the betterment of the community and the world.

Resilience
A person who is resilient has emotional strength and perseveres in the face of challenges. He manifests courage, optimism, adaptability and resourcefulness.

Harmony
A person who values harmony seeks inner happiness and promotes social cohesion. He appreciates the unity and diversity of a multicultural society.

The development of social and emotional competencies alongside the development of these core values is also integral to the development of 21st century competencies. These social and emotional competencies are: (a) Self-awareness, (b) Self-management, (c) Social Awareness, (d) Relationship Management, and (e) Responsible Decision Making.

Self-awareness
Self-awareness relates to one's understanding of one's own emotions, strengths, inclination and weaknesses. It includes:

- Identifying and recognising emotions
- Accurate self-perception
- Recognising strengths, needs, and values
- Self-efficacy
- Spirituality

Self-management
Self-management relates to one's capacity to manage one's emotions, self-motivate, exercise discipline and organisational skills. This includes:

- Impulse control and stress management
- Self-motivation and discipline
- Goal-setting and organisational skills

Social Awareness
Social awareness relates to one's ability to accurately perceive perspectives, empathise, recognise and appreciate diversity and respect others. It includes:

- Perspective taking
- Empathy
- Appreciating diversity
- Respect for others

Relationship Management
Relationship management relates to one's ability to establish and maintain healthy and rewarding relationships through effective communication, engagement and providing help. This includes:

- Communication, social engagements and building relationships
- Working cooperatively
- Negotiation, refusal and conflict management
- Seeking and providing help

Responsible Decision Making
Responsible Decision Making relates to one's capacity to identify and analyse the situation for problem solving, and to reflect upon the implications of decisions made, based on personal, moral and ethical considerations. This includes:

- Problem identification and situation-analysis
- Problem-solving
- The ability to evaluate and reflect on the situation
- Personal, moral, and ethical responsibility.

Competency domains gaining prominence in the 21st century are (a) Civic Literacy, Global Awareness and Cross-cultural Skills, (b) Critical and Inventive Thinking, and (c) Information and Communication Skills.

Civic Literacy, Global Awareness and Cross-cultural Skills

Civic Literacy encompasses:

- The knowledge and consciousness of our national identity and home environment.
- An active interest in improving the home environment and the lives of its people.

Global Awareness and Cross-cultural skills encompass:

- The recognition and understanding that we live in a global community and form inter-relationships among international organisations, nation-states, public and private economic entities, socio-cultural groups, and individuals across the globe.
- The ability to work appropriately and productively as well leverage on the collective intelligence of groups when appropriate.

Critical and Inventive Thinking

Critical and inventive thinking encompasses the following:

- Critical thinking
    - Exercising sound reasoning in understanding – use varied types of reasoning as appropriate to the situation.
    - Making judgements and decisions – analyse and evaluate evidence, points of view and beliefs; interpret information and draw conclusions; as well as reflect critically on experiences.
    - Understanding the interconnections among systems – Analyse how parts of as whole interact with each other to produce overall outcomes of a complex system.
- Curiosity – the desire to know or explore novel elements in the environment by being tolerant of ambiguity and moving toward or asking questions of elements.
- Risk taking – the willingness to make mistakes and tackle challenging problems even without obvious solutions and when success is uncertain.
- Acting on creative ideas to make some specific and tangible difference in the domain in which the innovation occurs.
- Managing complexities – modify one's thinking, attitude, or behaviour to manage complexities and to handle multiple goals, tasks, and inputs.

Information and Communication Skills

Information and communication skills would include:

- Being open and responsive to new and diverse perspectives
- Accessing information effectively for the issue at hand
- Managing the flow of information from a variety of sources and using technology, communication networks and electronic resources
- Understanding ethical / legal issues surrounding the access and use of information and demonstrating responsible behaviour
- Developing, implementing and communicating new ideas to others in diverse environments

AIMS

The Secondary Science Normal (Technical) Syllabus aims are to:

(i) guide students in acquiring knowledge with understanding for **application in their daily lives** such that they:

- are motivated to learn science through contextual and hands-on learning;
- are able to problem-solve and use thinking and inquiry processes;
- can communicate effectively;
- develop safety consciousness and safe practice;
- become confident citizens who are able to cope with the changing and progressive nature of science and technology in the world.

(ii) enable students to **develop 21st century competencies** which would:

- enable them to acquire problem-solving skills and use thinking and inquiry processes;
- enable them to become responsible individuals and productive citizens;
- enable them to acquire life-long learning skills;
- enable them to show care and concern for people and the environment;
- allow them to use information communications technology (ICT) for communications, collaboration and as a tool for data collection and the analysis of results.

(iii) enable students to be **suitably prepared for post-secondary courses**, such that they:

- develop abilities and skills which would also be relevant and useful in the work place;
- become aware of the impact of science and technology on society, industry, and business.

It is hoped that where appropriate, teachers should allow students to have the opportunities to discuss the ethical implications of science and technology.

SYLLABUS FRAMEWORK

The Lower Secondary Normal (Technical) Science syllabus comprises:

Knowledge, skills and attitudes that all students should acquire	80% of curriculum time
Compulsory inquiry-based activities to ensure students acquire scientific inquiry skills	
White space	20% of curriculum time

The white space is freed up curriculum time for Lower Secondary to enable science teachers to use more interactive and engaging teaching and learning approaches, and/or to implement school-based curriculum. This flexibility enables teachers to better cater for the range of abilities, interests and needs of their students, as long as the aims of the syllabus are met.

A Knowledge with Understanding and Application

The syllabus is organised around contexts that students can relate to in their everyday experiences and are commonly observed phenomena.

The subject matter has been structured into six core modules in the syllabus. They are **Gadgets Work Wonders (I), Matter Around Us and Wonders of My Body (I) at** the Lower Secondary, and **Gadgets Work Wonders (II), Food Matters, and Wonders of My Body (II)** at the Upper Secondary.

These contexts provide a strong link to facilitate learning of the fundamental Science concepts and to understand their applications in authentic, real life situations. Each core module comprises 3 to 5 topics; the teaching and learning of the topics within a module should be viewed as interlinked and not as compartmentalised blocks of knowledge.

The concepts in each of the core modules are built around key inquiry questions[1]. These questions provide an overarching frame to guide instruction and learning of the important Science concepts and process skills. Teachers could delve further using the key inquiry questions as a starting base, to a series of related sub-questions, to facilitate students understanding of the interconnections of the concepts being taught.

[1] Reference: Wiggins, J and McTighe, J. (1998). *Understanding by Design.* Alexandria, Va.: Association for Supervision and Curriculum Development.

As an example, in the module **"Gadgets Work Wonders (I)"**, students are introduced to energy sources and their uses, the effects of forces, heat and electricity. For this module, the key inquiry questions are:

- How do gadgets use force and energy to make our lives better?
- How do energy conversions affect our lives?
- Why is heat important?
- Why is it important to conserve the use of energy?
- How does electricity work and how can it be used safely?

The six core modules are compulsory. There is no particular order in which the modules within each level should be taught.

Table 1 provides an overview of the syllabus content.

Table 1: Overview of Syllabus Content

Lower Secondary			
Module	**Gadgets Work Wonders (I)**	**Matter Around Us**	**Wonders of My Body (I)**
Topics	• Exploring Forces • Discovering Energy • Investigating Heat • Investigating Electricity 1 Key Inquiry Activity	• Properties of Matter • Water, Solutions and Suspensions • Water pollution • Air pollution 1 Key Inquiry Activity	• Cells: Basic Units of Life • Getting Energy & Nutrients from Food • Human Reproduction • Taking Good Care of My Body 1 Key Inquiry Activity
Upper Secondary			
Module	**Gadgets Work Wonders (II)**	**Food Matters**	**Wonders of My Body (II)**
Topics	• Energy and its Uses • Energy transfer through Waves • Effects of Forces • Electricity • Sources of Electricity 2 Key Inquiry Activities	• Sources of Food • Food Chemistry • Food Health and Safety 2 Key Inquiry Activities	• Digestion • Breathing • Fitness and Cardiac Health • Staying Healthy 2 Key Inquiry Activities

B Skills and Processes

In this syllabus, teachers are encouraged to provide opportunities for students to use concepts and integrate skills and processes to inquire about science around them.

<table>
<tr><th>Skills and Processes</th><th>Engaging with an event, phenomenon or problem through:</th><th>Collecting and presenting evidence through:</th><th>Making meaning of information and evidence through:</th></tr>
<tr><td rowspan="2">Skills</td><td>• Posing questions
• Formulating hypothesis
• Defining the problem
• Generating possibilities
• Predicting</td><td>• Observing
• Using apparatus and equipment</td><td>• Comparing
• Classifying
• Inferring
• Analyzing
• Elaborating
• Verifying</td></tr>
<tr><td colspan="3">Communicating</td></tr>
<tr><td>Processes</td><td colspan="3">Creative problem-solving, Planning investigation and Decision-making</td></tr>
<tr><td rowspan="2">Essential Features of Inquiry</td><td>Question</td><td>Evidence</td><td>Explain Connect</td></tr>
<tr><td colspan="3">Communication</td></tr>
</table>

Skills

Engaging with an event, phenomenon or problem through:

Posing questions
This is the skill involving the clarification of issues and meaning through inquiry. Good questions focus attention on important information and are designed to generate new information.

Formulating hypothesis
This is the skill of making a general explanation for a related set of observations or events. It is an extension of inferring.

Defining the problem
This is the skill where one makes conscious effort to clarify situations that are puzzling in some way. The extent, scope and nature of the problem are identified and clarified.

Generating possibilities
This is the skill of exploring all the alternatives, possibilities and choices beyond the obvious or preferred one.

Predicting
This is the skill of assessing the likelihood of an outcome based on prior knowledge of how things usually turn out.

Collecting and presenting evidence through:

Observing
This is the skill of using our senses to gather qualitative as well as quantitative information about a particular object, event or phenomenon. This also includes the use of instruments to extend the range of our senses.

Using apparatus and equipment
This is the skill of knowing the functions and limitations of various equipment and apparatus, and being able to select and handle them appropriately for various tasks.

Making meaning of information and evidence through:

Comparing
This is the skill of identifying the similarities and differences between or among objects or entities.

Classifying
This is the skill of grouping objects or events according to common attributes or properties.

Inferring
This is the skill of interpreting and explaining observations, data or information gathered.

Analysing
This is the skill of clarifying information by examining parts and relationships contained in the information.

Elaborating
This is the skill of providing details, examples and other relevant information so as to make one's ideas more comprehensible to others.

Verifying
This is the skill of confirming or proving the truth of an idea, using specific standards or criteria of evaluation.

Communicating:

This is the skill of transmitting and receiving information presented in various forms - verbal, tabular, graphical or pictorial.

Processes

Processes are complex operations which call upon the use of several skills.

Creative problem solving
This is the process of thinking through a problem and choosing an innovative solution that meets the requirements. This thinking process is used whenever one faces obstacles and wishes to overcome them so as to arrive at a practical and workable solution.

Planning Investigation
This process involves formulating questions or hypotheses for investigating and devising ways to find answers. It also involves deciding on the type of equipment required, and measurements to be made, as well as identifying the variables involved and manipulating the variables so that the effect of only one variable can be observed in any one experiment.

Decision-making
Decision-making is the process of establishing and applying criteria to select from among seemingly equal alternatives. The process of establishing criteria involves consideration of the consequences and values and the ability to defend the reasons for the decision.

It must be pointed out that there is also no one definite sequence of priority among the skills and processes listed above. For example, observation may lead to hypothesising but at other times a hypothesis can lead to observation. All the skills and processes listed above are seen as part of the total process of scientific inquiry.

In science teaching and learning, effort should initially be directed at teaching explicitly each of the skills through the use of appropriate activities. Later, effort should be directed to helping students integrate some or all of the skills in scientific inquiry.

C Ethics and Attitudes

In all scientific inquiry, the adoption of certain mental attitudes such as *curiosity, creativity, objectivity, integrity, open-mindedness, perseverance* and *responsibility* are advocated. Attempts should also be made to promote safety consciousness among students and to encourage students to adopt safe practices.

Curiosity
This is the attitude of desiring to explore the environment and question what is found.

Creativity
This is the attitude of seeking innovative and relevant ways to solve problems.

Objectivity
This is the attitude of seeking data and information to validate observations and explanations objectively.

Integrity
This is the attitude of handling and communicating data and information with integrity.

Open-mindedness
This is the attitude of accepting all knowledge as tentative and the willingness to change their views if the evidence is convincing.

Perseverance
This is the attitude of pursuing a problem until a satisfactory solution is found.

Responsibility

This is the attitude of showing care and concern for living things and awareness of our responsibility for the quality of the environment.

Opportunities should be provided in the classroom for students to ask questions. Students should be encouraged to ask both closed and open questions. From the type of questions asked by the students, teachers could gather information on their ‘frame of mind’ and the quality of their understanding.

2 Teaching and Learning

TEACHING AND LEARNING THROUGH INQUIRY

What is scientific inquiry?

Scientific inquiry may be defined as the activities and processes which scientists and students engage in to study the natural and physical world around us. In its simplest form, scientific inquiry may be seen as consisting of two critical aspects: the what (content) and the how (process) of understanding the world we live in[2].

Teaching science as inquiry must therefore go beyond merely presenting the facts and the outcomes of scientific investigations. Students need to be shown how the products of scientific investigations were derived by scientists and be provided with opportunities to: ask questions about knowledge and issues that relate to their daily lives, society and the environment; be actively engaged in the collection and use of evidence; formulate and communicate explanations based on scientific knowledge.

Through inquiry learning, students will be able to acquire knowledge and understanding of their natural and physical world based on their own investigations, apply the skills and processes of inquiry and develop attitudes and values that are essential to the practice of science.

What are some characteristics of teaching and learning of science as inquiry?

Inquiry-based learning may be characterised by the degree of responsibility students have in posing and responding to questions, designing investigations, and evaluating and communicating their learning (student-directed inquiry) compared to the degree of responsibility the teacher takes (teacher-guided inquiry). Students will best benefit from experiences that vary between these two inquiry approaches.

Essential features of science as inquiry	**More ← Amount of Student Self-Direction → Less** **Less ← Amount of Guidance from Teacher or Material → More**			
Question Students engage with an event, phenomenon or problem when they …	pose a question	select among questions	sharpen or clarify question provided	accept given question
Evidence Students give priority to evidence when they …	determine what constitutes evidence and collects it	are directed to collect certain data	are given data and asked to analyse	are given data and told how to analyse

[2] Reference: Chiappetta, E. L., Koballa, T., Collette, A. T. (2002). *Science instruction in the middle and secondary schools.* Upper Saddle River, NJ: Merrill/Prentice Hall

Essential features of science as inquiry	More ← Amount of Student Self-Direction → Less Less ← Amount of Guidance from Teacher or Material → More			
Explanation Students construct explanations when they …	formulate their own explanation after summarising evidence	are guided in process of formulating explanation from evidence	are given possible ways to use evidence to formulate explanation	are provided with evidence
Connections Students evaluate their explanations when they …	examine other resources and form links to explanations	are directed toward sources of knowledge	are given possible connections	are provided with connections
Communication Students communicate and justify their explanations when they …	form reasonable and logical argument to communicate explanations	are coached in development of communication	are provided guidelines for communication	are given steps and procedures for communication

Adapted from *Inquiry and the National Science Education Standards*, National Research Council (2000).

What are some strategies for conducting inquiry-based learning and teaching?

A primary purpose for inquiry-based instruction is for students to learn fundamental science concepts, principles, and theories as well as to develop science process skills and attitudes that are essential for scientific inquiry. Science teachers are already using a variety of teaching strategies in their lessons.

To further emphasise the learning of science as inquiry, teachers can incorporate in these strategies the essential features of **Question, Evidence, Explanation, Connections and Communication** and provide students with experiences that varies between guided (partial) and open (full) inquiry.

The inquiry activities should be situated in *realistic contexts* to help students see the relevance and make connections between the science concepts they are learning and their daily lives.

Teachers are also encouraged to use a variety of strategies (e.g. demonstrations, field trips, concept mapping, games, model building) to facilitate the inquiry process.

CONTEXTUALISED LEARNING AND SCIENTIFIC LITERACY

What is contextualised learning?

The Science Curriculum Framework envisions the learning of science in contexts relevant and related to daily life, society and the environment to make the subject real and meaningful to the learners.

Contextualised learning is an instructional approach that places the learning of academic content (scientific knowledge and skills) in situations or issues (contexts) that are authentic and meaningful to the learners.

One of the goals of context-based science teaching and science education is greater engagement of students and developing their interest in science. A good and meaningful context draws learners into asking questions and seeking knowledge that can help them gain a deeper understanding of the topic. Two examples of contextualised learning are given below:

- Students learn about paper chromatography in the context of finding out what makes up the colourings used in candies
- Students learn about of electric circuits in the context of finding out how bulbs are connected in festive lightings.

Both of these familiar contexts provide students with the impetus to better understand the application of scientific principles in concrete terms.

Presenting scientific principles in contexts that students can identify with helps to build up their conceptual understanding of these principles. This is consistent with the second principle of learning identified by the National Research Council[3] which emphasises the importance of both factual and conceptual knowledge in learning Science. The grasp of factual know-how is augmented by conceptual knowledge, and likewise the understanding of conceptual knowledge is enhanced when it is used to organise and explain factual knowledge.

Contextualised learning provides a frame and guidance for students to understand the scientific concepts at work in different real life situations. For instance, the concept of indicators as substances that change colour is enhanced when students are given the chance to use two common types of indicators and observe the colour change when added in acids and alkalis. Students could then understand the importance of knowing the acidity and alkalinity of common household items and solutions.

How does contextualised learning develop scientific literacy?

Part of the definition of scientific literacy by the Programme for International Student Assessment (PISA) is for students to have scientific knowledge and the ability to "use of that knowledge to identify questions, acquire new knowledge,

[3] National Research Council (2005). *How Students Learn: Science in the Classroom.* Committee on *How People Learn,* A Targeted Report for Teachers. M.S. Donovan, J.D. Bransford (Eds.). Division of Behavioral and Social Science and Education. Washington DC: The National Academies Press.

explain scientific phenomena and draw evidence-based conclusions about science-related issues"[4].

Contextualised learning supports the development of this aspect of scientific literacy by providing students with contexts and opportunities to ask questions and learn about science-related issues and phenomena.

What are the strategies for contextualised learning?

The key feature of contextualised learning is the use of authentic contexts that are knitted closely and explicitly together with the scientific concept and skills during teaching and learning. They are learner-centred as students are actively involved in making connections between the conceptual learning and authentic experience.

The conduct of scientific investigations is another strategy for contextualised learning. Students are presented with an real problem situation which they can relate to and understand, and they are subsequently engaged to think about what to do, how go about doing it, how to make sense of it (reasoning) and to make decisions (conclusion).

Other inquiry-based strategies such as problem solving or model building can also be used for contextualised learning. Explicit real life contexts presented in these strategies will allow students to understand how they can make use of the scientific principles they have learned in new contexts.

[4] Organisation for Economic Co-operation and Development (OECD). (2009). PISA 2009 Assessment Framework: Key competencies in reading, mathematics and science. Retrieved from http://www.oecd.org/dataoecd/11/40/44455820.pdf on August 04, 2012.

LEVERAGING ON INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) FOR TEACHING AND LEARNING

In a comprehensive literature review on science education and the role of ICT, Osborne and Hennessy (2003)[5] gave a broad overview of the ICT tools suitable for science education by grouping them into 5 categories:

1. Tools for data capture, processing and interpretation
2. Multimedia software
3. Information systems
4. Publishing and presentation tools
5. Computer projection technology

The first category which includes datalogger, data analysis software and spreadsheet are used by teachers to support practical work and scientific inquiry activities.

The second category includes simulation software and virtual experiments that allow students to visualise complex processes and concepts and perform virtual experiments which cannot be conducted in real-life due to their dangerous nature or lack of materials. Interactive simulations that allow students to manipulate one variable to see the effects on another variable can develop understanding of their relationships.

Internet and CD-ROM fall into the third category. These tools provide information that students can use in their scientific work, e.g. checking if their explanations are accepted by the science community.

The last two categories of ICT tools include digital camera, video recorder, 'PowerPoint' software and projector which allow students to capture images to support their scientific arguments and communicate effectively to fellow learners.

Online collaboration tools can also be used by science teachers to foster student participation in discussion of results of experiment or science-related issues. These tools can also provide teachers with evidence on students learning as part of formative assessment.

In selecting ICT tools to be used in their science classroom, science teachers should consider the suitability of the ICT tools in terms of their students' abilities and the added value that these tools will bring to the learning of the students.

[5] Osborne, R.J. & Hennessy, S. (2003). Literature Review in Science Education and the Role of ICT: Promise, Problems and Future Directions (NESTA Futurelab). Available online at: http//www.nestafuturelab.org/research/lit_reviews.htm (access 4 March 2005).

3 Syllabus Content

LOWER SECONDARY NORMAL (TECHNICAL) SCIENCE

Module 1: **Gadgets Work Wonders (I)** ▪ Exploring Forces ▪ Discovering Energy ▪ Investigating Heat ▪ Investigating Electricity	**Overview** Gadgets are tools or machines that perform different functions. They occupy a central role in our daily lives. In this module, students will learn about forces and energy needed for gadgets to work. When gadgets are in use, energy conversions take place. Two common forms of energy are heat and electrical energy. Energy sources such as fossil fuels are limited resources; it is therefore important for us to conserve the use of energy where possible.	**Key Inquiry Questions** • How do gadgets use force and energy to make our lives better? • How do energy conversions affect our lives? • Why is heat important? • Why is it important to conserve the use of energy? • How does electricity work and how can it be used safely?

Topic Description	**Learning Outcomes**		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Exploring Forces Although forces cannot be seen, many of their effects are observed in our daily lives. These effects of forces have useful and important applications. Simple machines such as levers and pulleys operate on forces. Many of these simple machines allow us to use a small force to overcome a large load. These simple machines are good examples of how technology and gadgets have made our work easier and increased our productivity.	▪ state that a force can change the shape, size, state of rest and motion of a body ▪ use newton as the unit of force ▪ give examples of different forces: pushing, lifting, stretching, twisting, pressing, gravitational, frictional and magnetic forces ▪ describe the effects of friction on the motion of an object ▪ identify the different types of simple machines (levers, inclined planes and pulleys) and give everyday examples of their use	▪ infer the effects of forces such as: - change in state of rest of motion of a body - change in size and /or shape of a body ▪ use a spring balance to measure force ▪ investigate the effort used when the following is used to raise a load: - lever - inclined plane - pulley	▪ appreciate science for its usefulness in improving quality of life: knowledge about force has allowed human to design many useful tools such as the simple machines

Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Discovering Energy Different gadgets require different forms of energy to work. When gadgets are in use, energy is changed from one form to another. Currently, the main source of energy for our country comes from fossil fuels, a non-renewable source of energy. Fossil fuels are limited resources which will be depleted one day. It is thus important to conserve energy where possible. There is also an urgent need to find and use alternative and renewable sources of energy.	▪ recognise and give examples of different forms of energy in everyday life (potential energy, kinetic energy, light energy, heat energy, electrical energy and sound energy)	▪ investigate energy conversion from one form to another ▪ compare the differences between renewable sources of energy (solar, wind, biomass, hydro) and non-renewable sources of energy (coal, oil and natural gas), and their limitations	▪ appreciate that fossil fuels are exhaustible and the need and ways to reduce energy wastage ▪ appreciate the importance of conserving energy in our daily lives because Singapore is dependent on imported fossil fuels to meet its energy needs

Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Investigating Heat Heat is important to human life. Heat is used to cook food and to keep people warm. We detect heat using our sense of touch. Thermometers are used to measure temperature to determine how hot or cold an object is. Effects of heat such as expansion and contraction have many important applications in our daily lives. However, some of these effects are undesirable as they can cause damages to buildings and structures.	▪ explain that heat is a form of energy that flows from a hotter to a colder region ▪ state the importance of heat energy in our life ▪ understand that temperature is a measure of the degree of hotness and coldness of an object ▪ recognise that when the temperature of a substance increases, the substance has absorbed heat; when the temperature of a substance decreases, the substance has lost heat ▪ recognise that there are different types of thermometers (digital thermometer, laboratory thermometer and temperature sensors) ▪ describe some consequences and applications of expansion and contraction in everyday life	▪ infer that generally, solids, liquids and gases expand when heated and contract when cooled ▪ measure temperature using a thermometer or a datalogger with temperature sensors	▪ appreciate science for its usefulness in improving quality of life: knowledge of heat allows us to tap on its usefulness and reduce its harmful effects

Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Investigating Electricity Electricity is another important form of energy. It is used to power gadgets which require electrical energy to work. Electrical gadgets and appliances are used to convert electrical energy to other forms of energy, e.g. an electric iron converts electrical energy to heat energy. Improper use of electricity will pose dangers to lives. It is hence important to learn how to use electricity safely. As electricity in Singapore is mainly produced from fossil fuels, we should strive to use electricity responsibly so as to reduce unnecessary wastage.	▪ describe electricity as a useful form of energy in our life ▪ outline the process from the production of electricity to using it in our home with reference to the energy conversions that take place ▪ relate the electrical conducting properties of materials to their use in the various parts of electrical appliances / circuits ▪ explain what is meant by current, voltage and resistance and state their units ▪ identify series and parallel circuits ▪ explain why parallel circuits are widely used in household while series circuits are not ▪ state the hazards of using electricity in the following situations: - damaged insulation - overloaded circuits - damp conditions ▪ list some precautionary measures to ensure the safe use of electricity.	▪ use voltmeter / ammeter for electrical measurements ▪ draw and interpret circuit diagrams and set up circuits comprising electrical sources (cell and battery), switches, lamps, resistors (fixed), ammeters and voltmeters ▪ investigate and classify a variety of materials as insulators or conductors	▪ appreciate the importance of using electrical energy responsibly and safely ▪ appreciate science for its usefulness in improving quality of life – knowledge of electricity has provide us with a convenient source of energy that helps us do many useful things.

Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
	▪ state the importance of reducing electrical energy wastage		

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<tr>
<td>Module 2:
Matter around Us

▪ Properties of Matter
▪ Water, Solutions and Suspensions
▪ Water Pollution
▪ Air Pollution</td>
<td colspan="2">Overview
Matter is anything that has mass and occupies space. The air that surrounds us, the water that we drink, the gadgets that we use, and even our bodies are all made up of matter. In this module, students will learn about common properties of matter.

We use things made of different types of materials in our daily lives. These materials have different properties.
Water is a good solvent - a lot of substances can dissolve in water to form solutions. When the insoluble substances are mixed with water, suspensions are formed. Solutions and suspensions have important uses in homes, industries and medicine.

Water and air are important for human survival. Unfortunately, many parts of world are facing water and air pollution problems.</td>
<td>Key Inquiry Questions
• What is matter?
• How can materials be classified?
• How can substances in a mixture be separated?
• What are the differences between solutions and suspension?
• What impact do human activities have on the environment?</td>
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<td rowspan="2">Topic Description</td>
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<td>Knowledge with Understanding and Applications</td>
<td>Skills and Processes</td>
<td>Ethics and Attitudes</td>
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<tr>
<td>Properties of Matter

Matter is anything that has mass and occupies space. The air that surrounds us, the water that we drink, the gadgets that we use, and even our bodies are all made up of matter.

We use things made of different types of materials in our daily lives. Some examples of materials are metals, glass, wood, fabrics and plastics. These materials have different properties such as hardness, elasticity and electrical conductivity. Knowing the properties of materials helps us understand why certain materials are used to make certain things.</td>
<td>▪ distinguish between the three states of matter in terms of shape and volume

▪ describe materials in terms of physical properties such as hardness, elasticity, solubility, density, boiling/melting point, electrical and thermal conductivities

▪ relate knowledge of the properties of materials to their everyday use</td>
<td>▪ compare materials in terms of their physical properties

▪ classify materials into different groups (e.g. metals and non-metals; ceramics, plastics and fibres)

▪ investigate substances that can be extracted through the following separation techniques:
- filtration
- evaporation</td>
<td>▪ show curiosity to explore how filtration and evaporation can be used to separate substances into their constituents.

▪ show perseverance to complete the separation of a given mixture using filtration and separation.</td>
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Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Water, Solutions and Suspensions Water is a good solvent - a lot of substances can dissolve in water to form solutions. However, not all matter is soluble in water, e.g. chalk powder is insoluble in water. When the insoluble substances are mixed with water, suspensions are formed. Solutions and suspensions have important uses in homes, industries and medicine. Solutions and suspensions have different properties that distinguish one from the other. Both solutions and suspensions have important uses in homes, industries and medicine. Acids and alkalis are two types of solutions. Acids and alkalis can be differentiated through the use of indicators, which will show different colours in acidic and alkaline solutions.	▪ explain what is meant by the terms solute, solvent and solution ▪ recognise that water dissolves many substances ▪ give examples of uses of solvents and solutions in the home, industry and medicine ▪ show an understanding that indicators are substances that change colour when an acid or alkali is added to them ▪ describe acidity, neutrality and alkalinity in terms of the pH scale (whole numbers only)	▪ deduce the nature of solutions and suspensions by simple laboratory test (e.g. passing a beam of light, filtering using filter paper) ▪ investigate the factors that affect the solubility of materials (e.g. type of solute/solvent, temperature) ▪ investigate the factors that affect the rate of dissolving (e.g. temperature, surface area, stirring) ▪ investigate the effect of acidic, alkaline and neutral solutions on indicators (Universal and litmus indicators)	▪ show curiosity to learn about how universal indicator can be used to determine pH value of a solution

Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Water Pollution In Singapore, clean water runs from the water tap. The clean water is safe for drinking, cooking and washing. It is also important to have clean water for water-based activities such as swimming. There are some industries that require a constant supply of clean water for production of goods. As cities become more economically active and densely populated, activities such as improper disposal of wastes from factories and irresponsible human activities may cause water pollution. Knowing the common sources water pollutions and their harmful effects will enable us to play a part in maintaining a clean and safe living environment for all.	▪ state common types and sources of water pollution ▪ discuss some methods of water pollution control	▪ investigate the effects of water pollution on living things	▪ appreciate that water is a precious resource that can be polluted by human's activities ▪ appreciate that preventing water pollution is essential to ensure that Singapore has a long term supply of clean water ▪ appreciate that knowledge of science can be used to convert waste water into drinkable water to provide Singapore with an additional source of water supply

Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Air Pollution Clean air is needed for healthy living. Constant exposure to unclean air will cause breathing and other health problems. Human activities such as excessive burning of fossil fuels will cause air pollution. Besides affect the quality of air that we breathe in, air pollution will cause other environmental problems such as acid rains. It is important for all of us to play a part in preventing and reducing air pollution.	▪ state the names and sources of common air pollutants (carbon monoxide, sulfur dioxide and oxides of nitrogen) ▪ list the possible harmful effects of air pollutants through human activities (acid rain, greenhouse effect and haze from forest fires) ▪ discuss some ways to reduce air pollution	▪ investigate the effects of acid rain on the environment	▪ appreciate that air is an important matter that can be polluted by human's activities ▪ appreciate that clean air is important

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<td>Module 3:
Wonders of My Body (I)

▪ Cells: Basic Units of Life
▪ Getting Energy & Nutrients from Food
▪ Human Reproduction
▪ Taking Good Care of My Body</td>
<td colspan="2">Overview
Cells are basic building blocks of living things. Our bodies function efficiently because there are different types of cells in our bodies which perform specific functions. In this module, students will learn about cells and how different parts of our bodies work together.

Our bodies get energy and nutrients from the food we eat. Our digestive system plays the important role of breaking down the food. Breathing and transport are two other systems needed for the healthy functioning of the body.

Reproduction ensures the continuity of the human race. Our reproductive systems start to mature during puberty and physical changes will take place during this stage. There are harmful consequences of sexually transmitted infections, abortion and pre-marital sex.

Smoking, excessive consumption of alcohol and drug abuse can severely affect the condition of our bodies. Understanding the harmful effects and consequences of such activities helps us make informed decisions in maintaining good health.</td>
<td>Key Inquiry Questions
• What are the building blocks of living things?
• Where do we get the energy to live, work and play?
• How do humans reproduce?
• How can we take good care of our body?</td>
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<td rowspan="2">Topic Description</td>
<td colspan="3">Learning Outcomes</td>
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<td>Knowledge with Understanding and Applications</td>
<td>Skills and Processes</td>
<td>Ethics and Attitudes</td>
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<tr>
<td>Cells: Basic Units of Life

Cells are basic building blocks of living things. Our bodies function efficiently because there are different types of cells in our bodies, e.g. blood cells and bone cells, which perform specific functions.

Three of the parts in a typical animal cell are nucleus, cell membrane and cytoplasm. It is the genes in the nucleus that pass down traits from parents to children.</td>
<td>▪ state that all living things are made of cells, which are the basic units of life

▪ recognise that genes are found within the nucleus of a cell that control the traits of human and are passed from parents to children

▪ explain that the body can function efficiently by having different types of cells performing specific functions (bone cells, red blood cells, muscle cells)</td>
<td>▪ label on a drawing, the parts of a typical animal cell (cell membrane, cytoplasm, nucleus)</td>
<td>▪ appreciate the wonders of our bodies where many different types of cells work together effectively</td>
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Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Getting Energy & Nutrients from Food All living things need food to survive. Food provides both the energy needed by our bodies as well as the building blocks to help our bodies grow and repair themselves. To obtain energy and nutrients from the food we eat, our body needs to digest the food. This important task is performed by our digestive system.	▪ state the importance of digested food substances as being a source of energy and nutrients for building and repairing body tissues. ▪ describe briefly how the different parts of a digestive system helps in the digestion of food ▪ state that food is digested to form smaller substances that are carried by the blood to the other parts of the body ▪ state that when food is broken down to release the energy trapped within it, oxygen is required, and carbon dioxide and water are produced ▪ relate breathing to the body's need for oxygen and the need to get rid of carbon dioxide from the body	▪ investigate the role played by enzymes in the digestion of food (names of enzymes are not required) ▪ investigate the presence of carbon dioxide in exhaled air using limewater	▪ show curiosity to learn about the importance of digestion and breathing by asking questions ▪ show perseverance to complete an investigation on the difference between inhaled and exhaled air

Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Human Reproduction Reproduction is an essential life process to ensure the continuity of the human race. Reproductive systems start to mature during puberty and physical changes will take place during this stage. There are different methods of birth control and facilitated reproduction which married couples use for family planning. Sexually Transmitted Infections (STIs) such as syphilis, gonorrhoea and AIDS may cause permanent harm to the infected person. Abortion, the early termination of pregnancy, has both emotional and physical consequences. Sexual abstinence before marriage is the best way to protect oneself against these consequences.	▪ describe the functions of the various parts of the human male and female reproductive systems ▪ describe briefly the menstrual cycle and fertilisation ▪ show an awareness of some forms of facilitated reproduction in humans, e.g. in-vitro fertilisation and artificial insemination	▪ interpret and communicate data on the physical changes that occur during puberty and early adolescence ▪ compare a temporary and a permanent method of birth control	▪ recognise the importance of sample size in obtaining reliable evidence ▪ recognise the harmful consequences of sexually transmitted infections like syphilis, gonorrhoea and AIDS ▪ recognise the consequences relating to abortion and pre-marital sex

Topic Description	Learning Outcomes		
	Knowledge with Understanding and Applications	**Skills and Processes**	**Ethics and Attitudes**
Taking Good Care of My Body Our lifestyle choices will affect our health. Smoking, excessive consumption of alcohol and drug abuse will severely affect the condition of our bodies and prevent our bodies from functioning properly. Understanding the harmful effects and consequences of such activities can help us make informed decisions in maintaining good health.	▪ list some commonly abused drugs and inhalants ▪ list some harmful substances in tobacco smoke e.g. nicotine, carbon monoxide gas, tar and other cancer-causing substances	▪ investigate how lifestyle choices, i.e. drug abuse, consumption of alcohol and smoking, can affect personal health	▪ recognise the harmful effects and consequences of drug abuse such as depression, hallucination, addiction and related social problems like crimes and transmission of AIDS ▪ recognise the possible harmful effects of consumption of alcohol on the individual, his family and society ▪ recognise the possible harmful effects of smoking and passive smoke on a person's health such as bronchitis, lung cancer and heart disease ▪ recognise ways to avoid being addicted to drugs, alcohol and smoking

UPPER SECONDARY N(T) SCIENCE

Module 4: Gadgets Work Wonders (II) 1.1 Energy and its Uses 1.2 Energy Transfer through Waves 1.3 Effects of Forces 1.4 Electricity 1.5 Sources of Electricity	**Overview** This module builds on what students have learned in Lower Secondary about force and energy. When gadgets are in use, energy conversions take place. As technology advances, many gadgets use waves to transfer energy from one place to another. One group of waves called electromagnetic waves have many useful applications. One important effect of forces is to change the motion of objects. The motion of objects can be described in terms of the distance moved, speed and acceleration. Distance-time graph is useful to show how the distance travelled by an object changes with time. Electricity is a useful and important form of energy. It provides the energy needed by electrical gadgets to work. Because electricity poses a danger to life if not use properly, it is important to know how electricity works so as to use it safely.	**Key Inquiry Questions** • How do energy conversions affect our lives? • What are the uses of waves? • How does a force affect the motion of an object? • How does electricity work and how can it be used safely? • Where does electricity come from?
Topic Description	**Learning Outcomes** **Knowledge with Understanding and Applications Skills and Processes**	**Ethics and Attitudes**
1.1 Energy and its Uses Energy is the ability to do work. There are many different forms of energy such as kinetic energy, potential energy and thermal energy. Energy cannot be created or destroyed but can only be converted from one form to another. It is also through energy conversions that we obtain the form of energy we need, e.g. we burn gas to change the chemical potential energy in the gas to heat. Power is the rate which energy is used. When a high-power gadget is used, energy will be used at a very fast rate.	(a) show understanding that kinetic energy, elastic potential energy, gravitational potential energy, chemical potential energy and thermal energy are examples of different forms of energy (b) show understanding that thermal energy is transferred from a region of higher temperature to a region of lower temperature. (c) understand and apply the principle of the conservation of energy to daily situations (d) relate power to energy transferred and time taken, using appropriate examples and the equation; *power = energy / time* in simple systems	▪ show curiosity in learning about different forms of energy around us ▪ appreciate that fossil fuels are limited in supply and burning fossil fuels to obtain heat energy is a process that cannot be reversed

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
1.2 Energy Transfer through Waves A wave is a phenomenon in which energy is transferred through vibrations. A wave transfers energy but not the matter in the medium, e.g. a water wave transfers energy but not the water. The properties of waves are described using terms like the amplitude, frequency and wavelength. These properties enable us to make comparisons between different types of waves. A group of waves called electromagnetic waves have many useful applications such as TV remote control unit, microwave ovens and X-rays.	(a) describe what is meant by wave motion as illustrated by vibrations in ropes and springs (the terms transverse and longitudinal are not required) (b) show understanding that waves transfer energy (c) understand the terms frequency, wavelength, and amplitude of a wave (d) state how the following types of waves are used for daily situations i. radiowaves (e.g. radio and television communications) ii. microwaves (e.g. microwave oven and satellite communication) iii. infra-red (e.g. remote control devices) iv. light (e.g. optical fibres for telecommunication) v. ultra-violet (e.g. sunbeds and sterilisation) vi. X-ray (e.g. radiological and engineering applications)	▪ show curiosity in learning about how waves have impacted many areas of our daily lives, e.g. microwaves used by satellites enable us to watch sports events held in faraway countries ▪ appreciate science for its usefulness in improving quality of life: knowledge of waves has helped us use these waves for medical care, communication and improving productivity

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
1.3 Effects of Forces A force is a pull or push. One of the important effects of forces is to change the motion of objects. This effect is used in many daily activities such as moving and stopping vehicles and playing sports. The motion of objects can be described in terms of the distance moved, speed and acceleration. Distance-time graph shows how the distance travelled by an object changes with time. Interpreting the distance-time graph of an object allows deeper understanding of the motion of its object. Another important effect of forces is to produce a turning effect, which is also known as moment. We apply forces to produce moment when we open a door, sweep the floor with a broom, open a tin cover with a spoon and many other actions.	(a) use the following instruments for measuring length: rulers and measuring tape (b) use digital stopwatches for measuring time intervals (c) explain what is meant by speed and acceleration (d) calculate the average speed and acceleration (e) plot and interpret a distance-time graph of real situations (f) understand that a force can change the state of rest, and motion of a body (g) predict changes in speed and direction when a force acts on an object (h) understand what is meant by moment of a force and apply this to everyday examples (calculations are not required)	▪ show curiosity by asking questions about the importance of measurements in our daily lives ▪ appreciate science for its usefulness in improving quality of life: knowledge of force and moments has helped human design many useful tools ▪ show perseverance to complete an assigned task involving making measurements

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
1.4 Electricity Electricity is a useful and important source of energy in modern day living. It provides the energy needed to make electrical gadgets work. Electricity flows in electric circuits. Series and parallel circuits are two types of circuits which are used in home circuitry systems. To understand how electricity works, we need to understand voltage, current and resistance in both types of circuits. The labels on electrical gadgets provide useful information such as power. Using the information, we can calculate the quantity and cost of electricity. Improper use of electricity will pose dangers to lives. It is hence important to learn how to use electricity safety.	(a) measure current, voltage and resistance using a multimeter (b) draw simple series and parallel circuits for daily applications (e.g. table lamps use series circuits, ceiling lamps use parallel circuits) (c) label and interpret circuit diagrams which include cells, switches, resistors (fixed and variable), voltmeters, ammeters, bells, bulbs, lamps and fuses (d) state that current is the same at every point of a series circuit (e) state that the total current is equal to the sum of the currents of the individual branches in a parallel circuit (f) state that a voltage is required to cause a current flow (g) state that the effective resistance increases when in series circuit (h) state that the effective resistance decreases when in parallel circuit (i) identify situations in which series and parallel circuits are used in daily electrical circuitry systems (j) use information on a label of electrical appliance to determine its power consumption (k) give examples of ways to reduce electrical energy wastage at home (l) use the equations Power, $P = V \times I$, Energy, $E = P \times t$ (m) calculate the cost of using electrical appliance where the energy unit is kWh (n) understand and use information of electrical bills	▪ appreciate science for its usefulness in improving quality of life: knowledge of electricity has led to the invention of many useful appliances ▪ appreciate the importance of observing electrical safety precautions, e.g. not using wet hands to operate electrical appliances ▪ appreciate the importance and need to use electricity responsibly so as to reduce wastage ▪ show perseverance to complete an investigation involving making measurements with multimeters

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
	(o) identify the potential dangers in the use of electricity at home, such as i. damaged insulation ii. overheating of cables iii. poor or loose connections (p) state precautions to be taken for safe electrical use at home, such as i. use of fuses ii. earthing metal casings iii. double insulating wires iv. use of circuit breakers	

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
1.5 Sources of Electricity Electricity is generated in power stations. After electricity is generated at power stations, it is stepped up to a high voltage using transformers before transmission through a grid of high voltage transmission lines. Nearer to homes and offices, the electricity is stepped down to 230 V. Batteries provide us with a portable source of electrical energy. Many mobile devices such as mobile phones and laptop computers require batteries to work.	(a) outline the processes that produce electricity from fossil fuels to transmitting electricity to the homes, and consume electricity in common household electrical appliances (in terms of conversions of energy) (b) understand that electricity is transmitted from a power station through a grid of high voltage transmission lines (c) describe a transformer as two coils of wire wound onto a core of iron (d) understand the use of step-up and step-down transformers and give examples of their use (including high voltage transmission of electricity) (e) state the importance of batteries as a source of electricity, giving some examples of their use	▪ appreciate that fossil fuels are exhaustible and the need to reduce energy wastage ▪ appreciate the importance of conserving energy in our daily lives because Singapore is dependent on imported fossil fuels to meet its energy needs ▪ show curiosity by asking questions on the need to use transformers to stepped up and then stepped down electricity during transmission

Module 5: **Food Matters** 2.1 Sources of Food 2.2 Food Chemistry 2.3 Food Health and Safety	**Overview** In this module, students will learn about sources of food, extraction of substances from food mixtures, properties of food acids and common alkalis, and food health and safety. Food provides our bodies with energy and nutrients. As the world population increases, it is important that enough food is produced. To achieve that, the conditions needed for plants to grow need to be present. The food and drinks we consume are mostly mixtures that can be separated by physical methods. These methods are used at home and in industries. Food acids are found in common household food items such as vinegar. Acids have physical and chemical properties which have useful applications. A balanced diet is part of healthy living. Having a balanced diet means eating the right amount of different types of food. To prevent food from turning bad, preservation methods are used. Some of these methods involve the use of food additives. Besides preserving food, food additives are also added to provide nutrients and improve appearance and texture.	**Key Inquiry Questions** • How can enough food be produced to feed a growing population? • How can substances in food mixtures be extracted and separated? • What are the properties of food acids and common alkalis? • Why is it important to have a balanced diet? • How do we ensure our food is safe to eat?
Topic Description	**Learning Outcomes**	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
2.1 Sources of Food Food provides our bodies with energy and nutrients. As the world population increases, it is important that enough food is produced. To achieve that, the conditions needed for plants to grow need to be present. Fertilizers are used to provide nutrients to help plants grow faster and bigger. Chemical control	(a) state that sunlight, air, water and good soil (containing nutrients and appropriate pH) are required for plants to grow and produce food (b) measure the pH of soil using litmus paper, universal indicator or a pH meter (c) understand that fertilisers provide nutrients for the plant to grow faster and bigger (d) understand that the use of fertilisers can be beneficial (increase food supply) and also cause problems (e) state the effects of 'slash and burn' methods of agriculture on soil fertility and the environment (f) understand that pesticides and herbicides can be used to protect crops against	▪ show concern that due to the increasing world population there is a need to improve food production ▪ appreciate science for its usefulness in improving quality of life: knowledge of how plants grow has helped human improve food production ▪ show concern about agricultural methods that can harm the environment

(e.g. pesticides) and biological control (e.g. natural predators) can be used to protect the plants. Slash and burn is used in same countries as a cheap mean to clear land and make the soil fertile. However, this method can cause severe air pollution.	pests and weeds, and their use has effects on the environment (soil and water contamination) leading to effects on the food chain (g) describe and explain the use of biological control to reduce the use of pesticides (limited to the control of prey organisms by their predators) (h) understand that there is a need to improve the methods of food production: - as the world population increases - with limitations in space to grow food (i) describe how food production can be improved by: - improving plant and animal varieties - intensive production methods for crops, fish and farm animals (details of technologies are not required) (j) understand that plant hormones are used as weed killers and in regulating growth and ripening of fruits	▪ show perseverance to complete an assigned task to make a natural pH indicator to test acidity and alkalinity of common household items

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
2.2 Food Chemistry The food and drinks we consume are mostly mixtures that can be separated by physical methods. These methods are used at home and in industries. Chemical reactions take place when food decays and when food is cooked. During chemical reactions, new products are formed. Food acids are found in common household food items such as vinegar. Acids have physical and chemical properties. One property with important applications is the reaction with alkalis in a process called neutralisation.	(a) explain that substances can be extracted and separated through the following techniques: i. dissolving ii. filtration iii. evaporation iv. distillation v. paper chromatography (b) describe the applications of the various separation techniques in homes and food industries (c) use a measuring cylinder to measure volume of liquids / solids (d) describe a chemical reaction as a process that leads to the formation of new products (e) give examples of everyday changes that involve chemical reactions: i. decaying of food ii. burning iii. rusting iv. cooking of food (f) give examples of everyday situations in slowing down / preventing chemical reactions (e.g. preserving food, reducing amount of heat, fuel and air supply for burning, tin-plating against rusting) (g) describe the properties of acids by their taste and effects on litmus paper and universal indicator (h) describe acidity, neutrality and alkalinity in terms of the pH scale (whole numbers only) (i) measure the pH of various common household substances and food using homemade pH indicator, litmus paper, universal indicator and a pH meter	▪ appreciate science for its usefulness in improving quality of life: knowledge of microorganisms has helped humans treat wastes more effectively for a hygienic living environment ▪ show concern about harmful effects of disposing phosphate detergents and acidic waste water into water system ▪ striving for accuracy when making measurements with measuring cylinder ▪ show perseverance to complete an assigned task to investigate the food colourings used in a food sample

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
	(j) relate pH within the mouth to its effect on dental health (k) describe the characteristic properties of food acids on the following items that are commonly found at home : i. metals (e.g. cooking utensils) ii. bases (e.g. antacids) iii. carbonates (e.g. baking soda, effervescent Vitamin C tablets) (chemical equations are **not** required) (l) state that neutralisation takes place when an acid reacts with a base and the products are salt and water only (chemical equations are **not** required) (m) state some applications of neutralisation (e.g. action of toothpaste, fabric softener and hair conditioner, controlling of pH in soil, neutralising industrial wastes) (n) state some of the effects of phosphate detergents (e.g. increase growth of algae and water weeds) and acidic waste water on the rivers and seas (o) understand the use of microbes in sewage plants to treat the waste water before they are released to the rivers and seas	

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
2.3 Food Health and Safety A balanced diet is part of healthy living. Having a balanced diet means eating the right amount of different types of food. Balanced diet can be planned by looking at the nutrition labels of food. Food with high fat, salt and sugar should be consumed in moderation as they can cause health conditions. To prevent food from turning bad, preservation methods are used. Some of these methods involve the use of food additives. Besides preserving food, food additives are also added to provide nutrients and improve appearance and texture. The addition of non-permitted food additives, however, can cause serious health problems.	(a) understand the concept of a balanced diet as a diet supplying sufficient quantities of carbohydrates, proteins, fats, vitamins, mineral salts, fibre and water to sustain a healthy life (b) list the principal sources of carbohydrates, proteins, fats, vitamin C, vitamin D, mineral salts (calcium and iron only), fibre and water (c) state the dietary importance of carbohydrates, proteins, fats, vitamin C, vitamin D, mineral salts (calcium and iron only), fibre and water (d) understand the use of simple food tests on i. Starch (iodine test) ii. Protein (biuret's test) iii. Oil (blot test) [knowledge of detailed procedures of tests is <u>not</u> required] (e) identify the basic information found on a food/nutrition label such as carbohydrate, protein, fat and sodium content, serving sizes, % daily values, and energy content (in kilojoules and kilocalories) (f) understand and calculate percentages and total amount of a nutrient based on serving sizes and % daily values (the conversion between kilojoules and kilocalories is not required) (g) state how some food with high fat, salt and sugar contents can cause health conditions such as obesity, high blood pressure and diabetes (h) state what microbes are (i) describe the action of microbes on food (e.g. mould on bread and bacteria on milk) (j) state that to preserve food there is a need to reduce microbial activity	▪ appreciate that it is one's personal responsibility to adopt a balanced and healthy diet ▪ appreciate science for its usefulness in improving quality of life: knowledge of chemical change has helped human come out with effective means of preserving food and reducing food wastage ▪ show concern about the harmful effects of using non-permitted food additives and excessive use of permitted food additives

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
	(k) describe briefly the following methods of preventing food from getting spoilt: i. using high temperature (e.g. sterilisation, pasteurisation, canning) ii. using low temperature (e.g. freezing) iii. reducing the water content (e.g. freezing, dehydration, use of chemical preservatives) iv. lowering the pH (e.g. pickling) v. reducing the oxygen supply (e.g. bottling, packaging) (l) describe why some food additives are necessary (m) give examples of common food additives: i. preservatives (e.g. vinegar, salt, sugar, sulfur dioxide), ii. nutrient supplements (e.g. vitamins, mineral salts), iii. texture and appearance modifiers (e.g. starch, food colourings) (n) describe the dangers of using non-permitted additives (e.g. carcinogens, heavy-metal poisons) or adding excessive levels of permitted additives in food production (knowledge of specific non-permitted additives or permitted additives is <u>not</u> required)	

Module 6: **Wonders of My Body (II)** 3.1 Digestion 3.2 Breathing 3.3 Fitness and Cardiac Health 3.4 Staying Healthy	**Overview** In this module, the knowledge and understanding of the concepts in digestion, respiration and blood circulation are covered with more depth, building on what the students have learned in lower secondary N(T) Science. These three processes are inter-related and work together to provide our bodies with the energy needed to go about our daily activities and the nutrients needed for growth and repair.	**Key Inquiry Questions** • How do our digestive, respiratory and circulatory systems work together to support life? • How do the heart and lungs work to transport important nutrients around the body? • How can we keep fit and stay healthy?
Topic Description	**Learning Outcomes**	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
3.1 Digestion Digestion is the breakdown of food into simpler substances for absorption into the blood stream. Our body uses digested food for energy, growth and repair. Enzymes present in our digestive system require optimum temperature and pH to speed up the rate of digestion. Certain lifestyle choice such as excessive consumption of alcohol, and having inadequate liquids and fibres can also lead to health problems such as liver damage and constipation.	(a) explain why digestion is necessary for most food in order for our body to use food for energy, growth and repair (b) identify the main organs and the associated organs of the digestive system (mouth, gullet, stomach, small intestine, large intestine, rectum, anus, salivary glands, pancreas, gall bladder and liver) and state their functions (c) show an understanding that digestive enzymes are important in helping to speed up the rate of digestion, and that they require optimum temperature and pH to work efficiently (d) interpret data on the effect of pH and temperature on the rate of protein digestion by enzymes (e) describe the effects of excessive alcohol consumption on the liver (e.g. damaged liver, liver cancer) (f) outline how constipation may occur, and suggest how to prevent them (g) state how the diet and activity level of a diabetic person can be changed to control his/her blood glucose level	▪ show curiosity in learning about how our bodies work by asking questions ▪ recognise the possible harmful effects of consumption of alcohol on the individual, his family and society

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
3.2 Breathing Oxygen is needed by the body to release energy in digested food. In the process, carbon dioxide is produced. Breathing brings oxygen into our body and gets rid of carbon dioxide from our body. Unhealthy lifestyle choices can harm our respiratory system, e.g. smoking is linked to health problems such as bronchitis and lung cancer.	(a) describe why oxygen is important to us (to help break down food molecules in order to release the energy trapped in them) (b) explain why breathing is important to us (brings oxygen into the body, and gets rid of carbon dioxide from the body) (c) identify parts of the respiratory system (windpipe, bronchi, lungs, ribcage, diaphragm) on a diagram & state their functions (d) show an awareness of how choking can lead to death (e) explain the differences in composition of inhaled and exhaled air (f) infer that exhaled air has higher a higher concentration of carbon dioxide than inhaled air, using the limewater test (g) infer that exhaled air has a higher concentration of water vapour than inhaled air, using cobalt chloride paper test (h) discuss the effects of smoking/passive smoking on the respiratory system (bronchitis & lung cancer)	▪ recognise the possible harmful effects of smoking and passive smoke on a person's health such as bronchitis, lung cancer and heart disease

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
3.3 Fitness and Cardiac Health Our circulatory system transports oxygen and glucose to different parts of our body and carry carbon dioxide and other wastes away. The system consists of the heart, blood vessels (arteries, veins and capillaries) and blood. The health condition of our circulatory system is known as cardiac health. Cardiac health can be improved and maintained through a combination of healthy diet and regular exercise. When we exercise, our breathing and heart beat increase as more oxygen is needed by the body. Cardiac health can be affected by diets with that are high in cholesterol, salt and saturated fats, which leads to an increased risk of heart attack and stroke. One indicator of cardiac health is the blood pressure.	(a) distinguish between fitness (ability to do physical activity) and health (free from disease) (b) understand the purpose of blood carrying oxygen and glucose to and carrying carbon dioxide and wastes away from all parts of the body (c) list the components of blood as red blood cells, white blood cells, platelets, plasma (d) state the functions of the components of blood: i. Red blood cells- transport oxygen ii. White blood cells – to destroy bacteria and other foreign bodies, antibody formation and tissue rejection iii. Platelets – blood clotting iv. Plasma – transport of food substances, carbon dioxide (e) outline the path of blood flow through the heart and the lungs to replenish the oxygen content of the blood (f) state the structure of arteries, veins and capillaries and relate it to their functions (g) describe how cholesterol can restrict or block blood flow in arteries by forming plaques, hence affecting one's fitness and health (e.g. stroke and heart attack) (h) state that the flow of blood through the body is observed in the form of pulses, heart beat and blood pressure (i) relate pulse rate to heart beat (j) measure pulse rate and explain that exercise has an effect on pulse rate and breathing rate, because of the need for more oxygen to be carried to the exercising muscles	▪ appreciate science for its usefulness in explaining how our bodies work and help us make informed decisions to maintain a healthy body ▪ show concern that unhealthy diet and lifestyle habits may lead to heart problems ▪ show perseverance to complete investigation on the effect of exercise on pulse rate

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
	(k) interpret data that shows correlation between incidence of heart disease and several factors (include blood pressure, lifestyle habits, consumption levels of salt and saturated fats) (l) understand the structure of a joint and describe briefly some common problems related to the joints (including sprains, dislocation, arthritis) (m) describe briefly some common problems related to our bones (including fracture and osteoporosis)	

Topic Description	Learning Outcomes	
	Knowledge with Understanding and Applications Skills and Processes	**Ethics and Attitudes**
3.4 Staying Healthy To stay healthy, we need regular exercise, sufficient rest, and balanced and regular meals. An indicator of physical health is the Body Mass Index (BMI). When the BMI is not within the healthy range, a person may be at an increased risk of health related issues. Diseases affect our health adversely. There are two types of diseases: hereditary diseases which are passed from parents to children and diseases caused by viruses and bacteria. Anti-microbial agents and vaccinations can provide protection against diseases caused by bacteria and viruses. Current advances in medical technology can replace some functions of damaged organs, e.g. through kidney dialysis, so as to sustain life but there are, however, some limitations.	(a) state the importance of regular exercise, sufficient rest, and eating regular, balanced meals in maintaining good physical and mental health (b) give examples how modern lifestyle can cause harm to our health (e.g. eating fast food and convenience foods, prolonged use of the computer without break, prolonged listening to loud music using personal music devices) (c) infer if an individual's weight is in the healthy range by calculating his/her BMI = mass (kg) / [height(m) x height (m)] (d) describe some risks associated with over-dieting and over-exercising in an attempt to lose weight (e) understand that diseases can be caused by viruses and bacteria (details of structure is not required) (f) investigate the effects of anti-microbial agents (e.g. antiseptics, disinfectants) on the population growth of micro-organisms (e.g. bacteria, fungi) (g) understand that vaccination gives protection from certain viruses (h) understand the importance of completing a prescribed course of antibiotics (i) state that some diseases/conditions are hereditary by nature, i.e. passed through the parents' genes (e.g. thalassemia and colour blindness) (j) understand the use and limitations of technology in replacing malfunction organs (e.g. organ transplant, kidney dialysis)	▪ appreciate that it is one's personal responsibility to exercise regularly to maintain good physical health ▪ show concern about the harmful effects of over-dieting and over-exercising ▪ show perseverance to complete an investigation on the effectiveness of anti-septic hand wash on micro-organisms

4 Assessment

ASSESSING LOWER SECONDARY NORMAL (TECHNICAL) SCIENCE

Assessment is an integral part of the teaching and learning process. It involves gathering information through various assessment techniques and making sound decisions. Assessment provides information to the teacher about students' achievement in relation to the learning objectives. With this information, the teacher makes informed decisions about what should be done to improve teaching methods and enhance the learning of the students.

Why Assess?

Assessment measures the extent to which desired knowledge, skills and attitudes are attained by students. While it complements the teaching and learning process, it also provides formative and summative feedback to teachers, students, schools and parents.

- 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' achievement 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 also allows the schools to review the effectiveness of their instructional programme.

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

What to Assess?

The Lower Secondary Science Normal (Technical) Curriculum is designed with contextualised approaches and aims to develop students' 21st century competencies and scientific literacy. Assessment should, where possible, mirror and comprise items that are dynamic, relevant and current in the real world and context.

This should include the assessment of the knowledge, understanding and application of the science concepts, the ability to use process skills, and the development of attitudes important to the practice of science in authentic, relevant real-life contexts.

How to Assess?

Assessment measures the extent to which desired knowledge, skills and attitudes are attained by students. As it serves many purposes, it is important to match the type of assessment to the specific purpose for which it is intended.

Before making an assessment about a certain aspect of students' performance, the teacher should ensure that the assessment mode used will generate information that reflect accurately the particular aspect of performance the teacher intends to assess.

In an inquiry-based classroom, the assessment can take many forms. In addition to the written tests, teachers can also conduct performance based assessment using the following modes:

- Practical work
- Projects
- Teacher observations
- Checklists
- Reflections / Journals
- Model-making
- Posters
- Games and quizzes
- Debates
- Drama / Show and Tell
- Learning Trails

Teachers can also assess students through the use of portfolios. A portfolio is a systematic collection of students' work and provides a comprehensive picture of their achievement. The work collected provides a continuous record of the students' development and progress in the acquisition of knowledge, understanding of scientific concepts, application of process skills, and development of attitudes. It also provides opportunities for the students to carry out self-evaluation and reflections by revisiting their own portfolio.

The assessment modes listed above are by no means exhaustive. Adopting a variety of assessment modes enables the teachers to assess different aspects of teaching and learning. Teachers are also encouraged to explore the use ICT for formative assessment.

ASSESSMENT OBJECTIVES FOR UPPER SECONDARY NORMAL (TECHNICAL) SCIENCE[6]

A Knowledge with understanding

Students should be able to demonstrate knowledge and understanding in relation to:

1. scientific phenomena, facts, laws, definitions, concepts, theories;
2. scientific vocabulary, terminology and conventions (including symbols, quantities and units);
3. scientific instruments and apparatus including techniques of operation and aspects of safety;
4. scientific quantities and their determinations.

The subject content defines the factual knowledge that candidates may be required to recall and explain. Questions testing those objectives will often begin with one of the following words: define, state, name, describe, explain or outline. (See glossary of terms.)

B Handling and applying information

Students should be able – in words or by using symbolic, graphical and numerical forms of presentation – to:

1. locate, select, organise and present relevant information from a variety of sources;
2. transpose information from one form to another;
3. process numerical and qualitative data;
4. use information to identify patterns, report trends and draw inferences;
5. present reasoned explanations for phenomena, patterns and relationships;
6. make predictions.

These assessment objectives cannot be precisely specified in the subject content because questions testing such skills may be based on information which is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, reasoned or deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: predict, suggest, calculate or determine. (See glossary of terms.)

C Experimental Skills and Investigations

Students should be able to:

1. select and organise techniques, apparatus and materials;
2. take readings accurately;
3. handle experimental data and observations;
4. interpret and evaluate experimental results

Scientific subjects are, by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to facilitate the learning of this subject and to meet objectives C1– C4 above.

[6] Refer to SEAB website for most up-to-date assessment syllabus

SCHEME OF ASSESSMENT FOR UPPER SECONDARY NORMAL (TECHNICAL) SCIENCE[7]

There will be two papers.

Paper	Type of Paper	Duration	Marks	Weighting
1	Multiple Choice Questions	1 h	40	40%
2	Short-answer or structured	1 h 15 min	60	60%

Paper 1	The paper will consist of 40 compulsory multiple choice questions.
Paper 2	The paper will consist of a variable number of compulsory short-answer or structured questions. One of the questions is a data response question, requiring candidates to interpret, evaluate or solve problems using data and/or observations. This question will carry 8–12 marks.

Weighting of Assessment Objectives
Papers 1 and 2 (100 marks in total)

A **Knowledge with understanding**, approximately 60% of the marks with approximately one-third allocated to recall.

B **Handling and applying information**, approximately 40% of the marks.

Objectives A and B may be assessed through questions which involve experimental skills and investigations. These questions, when set, are also intended to meet appropriate aspects of objectives C1–C4.

Questions on experimental skills and investigations will normally be set within the bounds of the syllabus. If questions are based on apparatus or topics beyond the syllabus, candidates will not be assessed on knowledge of the apparatus or topics. They will be assessed on knowledge or general skills (e.g. reading of scales, data handling) which are required by the syllabus. Questions may be set requiring the candidates to:

(a) select appropriate experimental techniques;
(b) select and organise apparatus and materials;
(c) draw, complete or label diagrams of apparatus;
(d) record readings from diagrams of apparatus;
(e) read, complete or draw tables of data;
(f) take readings from or plot graphs;
(g) determine a gradient, intercept or intersection on a graph;
(h) interpret or draw conclusions from observations and experimental data;
(i) suggest a needed modification to a step in an experiment;
(j) recognise or comment on possible sources of error from experimental data;
(k) comment on the safety or suggest safety procedures when using apparatus, materials and techniques.

[7] Refer to SEAB website for most up-to-date assessment syllabus

5 Glossary of Terms

GLOSSARY OF TERMS

1. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

2. *Classify* requires candidates to group things based on common characteristics.

3. *Comment* is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.

4. *Compare* requires candidates to provide both similarities and differences between things or concepts.

5. *Define* (the term(s)…) is intended literally, only a formal statement or equivalent paraphrase being required.

6. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. In the latter instance the answer may often follow a standard pattern, e.g. Apparatus, Method, Measurement, Results and Precautions.

   In other contexts, *describe* and *give an account of* should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. *Describe and explain* may be coupled in a similar way to *state and explain.*

7. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula.

8. *Estimate* implies a reasoned order magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about the points of principle and about values of quantities not otherwise included in the question.

9. *Explain* may imply reasoning or some reference to theory, depending on the context.

10. *Find* is a general term that may be variously interpreted as calculate, measure, determine etc.

11. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should not be exceeded.

12. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

13. *Outline* implies brevity, i.e. restricting the answer to giving essentials.

14. *Predict* or *deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted from an earlier part of the question. Predict also implies a concise answer with no supporting statement required.

15. *Sketch*, when applied to graphic work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having the intercept, asymptote or discontinuity at a particular value.

    In diagrams, sketch implies that a simple, freehand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.

16. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.

17. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer, or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.

18. *What do you understand by/ What is meant by* (the term(s)…) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in light of the indicated mark value.

19. *Appreciate* implies the recognition of the value of a concept or situation.

20. *Discuss* implies giving a critical account of the points involved in the topics.

21. *Distinguish* requires students to identify and understand the differences between objects, concepts and processes.

22. *Identify* requires students to select and/or name the object, event, concept or process.

23. *Investigate* requires students to find out by carrying out experiments

24. *Recognise* requires students to identify facts, characteristics or concepts that are critical (relevant/appropriate) to the understanding of a situation, event, process or phenomenon.

25. *Relate* requires students to identify and explain the relationships between objects, concepts and processes.

26. Show an awareness implies having superficial knowledge of the concepts or processes.

27. Show an understanding implies the ability to recall, explain and apply information.

6 Acknowledgements

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