# Science

## Junior High

## Grade 10

# Teacher Guide

## Standards-Based

Papua New Guinea

Department of Education

'FREE ISSUE
NOT FOR SALE'

# Science
## Junior High

## Grade 10

# Teacher Guide

## Standards-Based

Papua New Guinea
Department of Education

**Issued free to schools by the Department of Education**

Published in 2020 by the Department of Education, Papua New Guinea



*First Edition*



*Graphic Design Layout by David Kuki Gerega*

ISBN 978-9980-906-21-2

# Contents

# Acknowledgements

The Science Teacher Guide for grade 10 was developed by the Curriculum Development Division of the Department of Education and was coordinated by John Kakas with the assistance from the Subject Curriculum Group (SCG) members and the writing team.

Teachers, School Inspectors, Teacher College Lecturers, community members, representatives from Non-Government Organizations (NGOs) and members of the public community assisted in the development of this Teacher's Guide through many workshops, meetings, and consultations. They are all acknowledged for their support and contributions.

Dr. Arnold Kukari, Technical Advisor - Curriculum, is acknowledged for his technical advice on the development of this teacher guide. Curriculum Panel (CP), Subject Advisory Committee (SAC), and Board of Studies (BoS) Committee members are also acknowledged for their consideration and endorsement of the Teacher Guide.

# Acronyms

| | |
|---|---|
| AAL | Assessment AS Learning |
| AFL | Assessment FOR Learning |
| AOL | Assessment OF Learning |
| SSBoS | Secondary School Board of Studies |
| CDD | Curriculum Development Division |
| CP | Curr iculum Panel |
| DA | Diagnostic Assessment |
| IHD | Integral Human Development |
| GoPNG | Government of PNG |
| OBC | Outcomes Based Curriculum |
| OBE | Outcomes Based Education |
| PNG | Papua New Guinea |
| SAC | Subject Advisory Committee |
| SBC | Standards Based Curriculum |
| SBE | Standards Based Education |
| SCG | Subject Curriculum Group |
| STEAM | Science, Technology, Engineering, Arts and Mathematics |

# Secretary's Message

The aims and goals of the SBC identify the important knowledge, skills, values, and attitudes that all students are expected to acquire and master in order to effectively function in society and actively contribute to its development, students' welfare and enable them to acquire and apply 21st Century knowledge, skills, values, and attitudes in their life after Grade 12.

Science education empowers students to be questioning, reflective and critical thinkers. It does this by giving students particular ways of looking at the world and by emphasising the importance of evidence in forming conclusions. Science education develops students' confidence to initiate and manage change to meet personal, vocational and societal needs. Science education assists students to be active citizens by providing the understandings they need to be informed contributors to debates about sensitive, moral, ethical and environmental issues.

An appreciation of scientific knowledge, processes and values has the potential to help students build a more productive and ecologically-sustainable environment. It is important that students in secondary schools appreciate and understand how the study of science presents them with opportunities for responsible decision making in their local, national and global communities.

Learning about science enables students to explore the organisation and structure of the social, economic, political and technological world. They learn how science and technology are inter-related, and how their applications shape the way humans live.
They analyse the pressures and processes which determine the priorities for research and the direction and development of science and technology. They become aware that the promised benefits of research should improve the quality of life and be shared as widely as possible.

I encourage teachers to read each section of the guide carefully and become familiar with the content of the subject specified in the teaching and learning and other sections of the guide. I also encourage teachers to try out your own ideas and strategies that you believe will effectively work in your schools for your students.

I approve and commend this Grade 10 Science Teacher Guide to be used by teachers in all Junior High Schools throughout Papua New Guinea.

…………………………….

**UKE. W KOMBRA, (PhD)**
Secretary for Education

# Introduction

This Grade 10 Science Teacher Guide is developed as a support document for the implementation of the Junior High Science Syllabus. It contains useful information that you should read and familiarize yourself with before you plan and teach the subject. The guidelines provided are translated from the content standards prescribed in the syllabus into teachable content.

The Teacher's Guide represents the present state of science expectations and is meant to be adjusted overtime. Its purpose is to support activities that advance standards based education practice and enhance classroom instruction. Such activities may include; formal study, dialogue and discussion, classroom observations, one-on-one professional development, coaching support, mentor-mentee collaborations, and other professional growth opportunities. Other suggested teaching and learning strategies provided in this guide will assist you to plan quality and interactive science lessons based on the knowledge, skills, attitudes and values from the benchmarks.

Students' employability will be enhanced through the study and application of STEAM principles. STEAM is an integral component of the core curriculum. All students are expected to study STEAM and use STEAM related skills to solve problems relating to both the natural and the physical environments. The aim of STEAM education is to create a STEAM literate society. It is envisioned that the study of STEAM will motivate students to pursue and take up academic programs and careers in STEAM related fields. STEAM has been embedded in the Science curriculum. Equal opportunities should be provided for all students to learn, apply and master STEAM principles and skills.

The teacher guide also contains samples of assessment tasks and rubrics that will help you to design quality assessments to measure students' performance against the intended content standards and evidence outcomes. The learning activities prepared must engage and motivate your students to think critically and communicate ideas freely with other students in their class.

Time allocation for Science is **240** minutes for grade 10.

# Structure of the Teacher Guide

There are four main parts to this teacher guide. They provide essential information on what all teachers should know and do to effectively implement the Chemistry curriculum.

***Part 1*** provides generic information to help the teachers to effectively use the teacher guide and the syllabus to plan, teach and assess students' performance and proficiency on the national content standards and grade-level benchmarks. The purpose of the teacher guide, syllabus and teacher guide alignment, and the four pillars of PNG SBC, that is, morals and values education, cognitive and high level thinking, and 21$^{st}$ Century thinking skills, STEAM, and core curriculum are explained to inform as well as guide the teachers so that they align SBE/ SBC aims and goals, overarching and SBC principles, content standards, grade-level benchmarks, learning objectives and best practice when planning lessons, teaching, and assessing students.

***Part 2*** provides information on the strands, units, topics and learning objectives. How topics and learning objectives are derived is explained to the teachers to guide them to use the learning objectives provided for planning, instruction and assessment. And to develop additional topics and learning objectives to meet the learning needs of their students and communities where necessary.

***Part 3*** provides information on SBC planning to help guide the teachers when planning SBC lessons. Elements and standards for SBC lesson plans are described as well as how to plan for underachievers, use evidence to plan lessons, and use differentiated instruction, amongst other teaching and learning strategies.

***Part 4*** provides information on standards-based assessment, inclusive of performance assessment and standards, standards-based evaluation, standards-based reporting, and standards-based monitoring. This information should help the teachers to effectively assess, evaluate, report and monitor demonstration of significant aspects of a benchmark.

The above components are linked and closely aligned. They should be connected to ensure that the intended learning outcomes and the expected quality of education standards are achieved. The close alignment of planning, instruction and assessment is critical to the attainment of learning standards.

# Purpose of the Teacher Guide

This teacher guide describes what all teachers should know and do to effectively plan, teach, and assess Grade 10 Science content to enable all students to attain the required learning and proficiency standards. The overarching purpose of this teacher guide is to help teachers to effectively plan, teach, assess, evaluate, report and monitor students' learning and mastery of national and grade-level expectations. That is, the essential knowledge, skills, values and attitudes (KSVAs) described in the content standards and grade-level benchmarks, and their achievement of the national and grade-level proficiency standards.

Ample information with thorough guidelines is provided for the teacher to use to achieve the essential KSVAs embedded in the set national content standards and grade level benchmarks. Thus, the teacher is expected to:

To this end, teachers are expected to:

- understand the significance of aligning all the elements of Standards-Based Curriculum (SBC) as the basis for achieving the expected level of education quality;
- effectively align all the components of SBC when planning, teaching, and assessing students' learning and levels of proficiency;
- effectively translate and align the Science syllabi and teacher guide to plan, teach and assess different Science units and topics, and the KSVAs described in the grade-level benchmarks;
- understand the Science national content standards, grade-level benchmarks, and evidence outcomes;
- effectively make sense of the content (KSVAs) described in the Science national content standards and the essential components of the content described in the grade-level benchmarks;
- effectively guide students to progressively learn and demonstrate proficiency on a range of Science skills, processes, concepts, ideas, principles, practices, values and attitudes;
- confidently interpret, translate and use Science content standards and benchmarks to determine the learning objectives and performance standards, and plan appropriately to enable all students to achieve these standards;
- embed the core curriculum in their Science lesson planning, instruction, and assessment to permit all students to learn and master the core KSVAs required of all students;

- provide opportunities for all students to understand how STEAM has and continues to shape the social, political, economic, cultural, and environment contexts and the consequences, and use STEAM principles, skills, process

- integrate cognitive skills (critical, creative, reasoning, decision-making, and problem-solving skills), high level thinking skills (analysis, synthesis and evaluation skills), values (personal, social, work, health, peace, relationship, sustaining values), and attitudes in lesson planning, instruction and assessment;

- meaningfully connect what students learn in Physics with what is learnt in other subjects to add value and enhance students' learning so that they can integrate what they learn and develop in-depth vertical and horizontal understanding of subject content;

- formulate effective SBC lesson plans using learning objectives identified for each of the topics;

- employ SBC assessment approaches to develop performance assessments to assess students' proficiency on a content standard or a component of the content standard described in the grade-level benchmark;

- effectively score and evaluate students' performance in relation to a core set of learning standards or criteria, and make sense of the data to ascertain students' status of progress towards meeting grade-level and nationally expected proficiency standards, and use evidence from the assessment of students' performance to develop effective evidence-based intervention strategies to help students' making inadequate or slow progress towards meeting the grade-level and national expectations to improve their learning and performance.

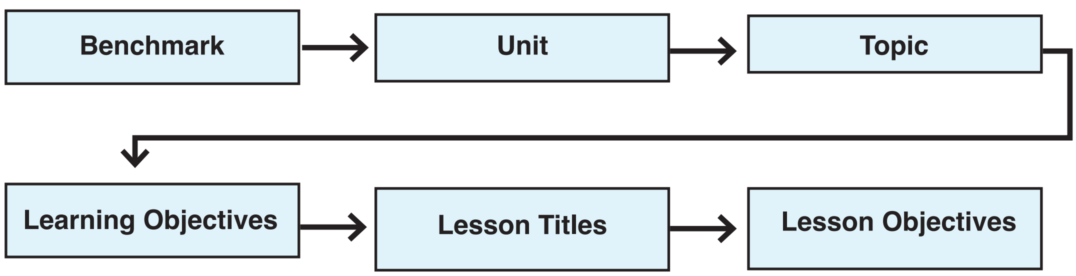
# How to use the Teacher Guide

Teacher Guide provides essential information about what the teacher needs to know and do to effectively plan, teach and assess students learning and proficiency on learning and performance standards. The different components of the teacher guide are closely aligned with SBC principles and practice, and all the other components of PNG SBC. It should be read in conjunction with the syllabus in order to understand what is expected of teachers and students to achieve the envisaged quality of education outcomes.

The first thing teachers should do is to read and understand each of the sections of the teacher guide to help them understand the key SBC concepts and ideas, alignment of PNG SBC components, alignment of the syllabus and teacher guide, setting of content standards and grade-level benchmarks, core curriculum, STEAM, curriculum integration, essential knowledge, skills, values and attitudes, strands, units and topics, learning objectives, SBC lesson planning, and SBC assessment. A thorough understanding of these components will help teachers meet the teacher expectations for implementing the SBC curriculum, and therefore the effective implementation of Grades 9 and 10 Science Curriculum. Based on this understanding, teachers should be able to effectively use the teacher guide to do the following:

## Determine Learning Objectives and Lesson Topics

Topics and learning objectives have been identified and described in the Teacher Guide. Lesson objectives are derived from topics that are extracted from the grade-level benchmarks. Lesson topics are deduced from the learning objectives. Teachers should familiarise themselves with this process as it is essential for lesson planning, instruction and assessment. However, depending on the context and students' learning abilities, teachers would be required to determine additional learning objectives and lesson topics. Teachers should use the examples provided in this teacher guide to formulate additional learning objectives and lesson topics to meet the educational or learning needs of their students.




## Identify and Teach Grade Appropriate Content

Grade appropriate content has been identified and scoped and sequenced using appropriate content organisation principles. The content is sequenced using the spiraling sequence principles. This sequencing of content will enable students to progressively learn the essential knowledge, skills, values and attitudes as they progress further into their schooling. What students learn in previous grades is reinforced and deepens in scope with an increase in the level of complexity and difficulty in the content and learning activities.

It is important to understand how the content is organised so that grade appropriate content and learning activities can be selected, if not already embedded in the benchmarks and learning objectives, to not only help students learn and master the content, but ensure that what is taught is rigorous, challenging, and comparable.

## Integrate the Core Curriculum in Lesson Planning, Instruction and Assessment

Teachers should use this teacher guide to help them integrate the core curriculum – values, cognitive and high level skills, 21st Century skills, STEAM principles and skills, and reading, writing, and communication skills in their lesson planning, instruction and assessment. All students in all subjects are required to learn and master these skills progressively through the education system.

## Integrate Cognitive, High Level, and 21st Century Skills in Lesson Planning, Instruction and Assessment

Teachers should integrate the cognitive, high level and 21st Century skills in their annual teaching programs, and give prominence to these skills in their lesson preparation, teaching and learning activities, performance assessment, and performance standards for measuring students' proficiency on these skills. Science addresses the skills and processes of sensitive, moral, ethical and environmental issues in the physical world and global industries. Thus, students will be able to make informed decisions, problem – solving and management knowledge, skills, values and attitudes in Science. This enables them to function effectively in the work and higher education environments as productive and useful citizens of a culturally diverse and democratic society in an interdependent world.

In addition, it envisaged all students attaining expected proficiency levels in these skills and will be ready to pursue careers and higher education academic programs that demand these skills, and use them in their everyday life after they leave school at the end of Grade 12. Teachers should use the teacher guide to help them to effectively embed these skills, particularly in their lesson planning and in the teaching and learning activities as well as in the assessment of students' application of the skills.

## Integrate Science Values and Attitudes in Lesson Planning, Instruction and Assessment

In science, students are expected to learn, promote and use work, relationship, peace, health, social, personal, family, community, national and global values in the work and study environments as well as in their conduct as community, national and global citizens. Teachers should draw from the information and suggestions provided in the syllabus and teacher guide to integrate values and attitudes in their lesson planning, instruction, and assessment. They should report on students' progression towards internalizing different values and attitudes and provide additional support to students who are yet to reach the internalization stage to make positive progress towards this level.

## Integrate Science, Technology, Engineering, Arts and Mathematics (STEAM) Principles and Skills in Lesson Planning, Instruction and Assessment

Teachers should draw from both the syllabus and teacher guide in order to help them integrate STEAM principles and skills, and methodologies in their lesson planning, instruction and assessment. STEAM teaching and learning happens both inside and outside of the classroom. Effective STEAM teaching and learning requires both the teacher and the student to participate as core investigators and learners, and to work in partnership and collaboration with relevant stakeholders to achieve maximum results. Teachers should use the syllabus, teacher guides and other resources to guide them to plan and implement this and other innovative and creative approaches to STEAM teaching and learning to make STEAM principles and skills learning fun and enjoyable and, at the same time, attain the intended quality of learning outcomes.

## Identify and Use Grade and Context Appropriate, Innovative, Differentiated and Creative Teaching and Learning Methodologies

SBC is an eclectic curriculum model. It is an amalgam of strengths of different curriculum types, including behavioural objectives, outcomes, and competency. Its emphasis is on students attaining clearly defined, measurable, observable and attainable learning standards, i.e., the expected level of education quality. Proficiency (competency) standards are expressed as performance standards/criteria and evidence outcomes, that is, what all students are expected to know (content) and do (application of content in real life or related situations) to indicate that they are meeting, have met or exceeded the learning standards. The selection of grade and contextually appropriate teaching and learning methodologies is critical to enabling all students to achieve the expected standard or quality of education. Teaching and learning methodologies must be aligned to the content, learning objective, and performance standard in order for the teacher to effectively teach and guide students towards meeting the performance standard for the lesson. They should be equitable and socially inclusive, differentiate, student-centred, and lifelong. They should enable STEAM principles and skills to be effectively taught and learned by students. Teachers should use the teacher guide to help them make informed decisions when selecting the types of teaching and learning methodologies to use in their teaching of the subject content, including STEAM principles and skills.

## Plan Standards-Based Lessons

SBC lesson planning is quite difficult to do. However, this will be easier with more practice and experience over time. Effective SBC lesson plans must meet the required standards or criteria so that the learning objectives and performance standards are closely aligned to attain the expected learning outcomes. Teachers should use the guidelines and standards for SBC lesson planning and examples of SBC lesson plans provided in the teacher guide to plan their lessons. When planning lessons, it is important for teachers to ensure that all SBC lesson planning standards or criteria are met. If standards are not met, instruction will not lead to the attainment of intended performance and proficiency standards. Therefore, students will not attain the national content standards and grade-level benchmarks.

## Use Standards-Based Assessment

Standards-Based Assessment has a number of components. These components are intertwined and serve to measure evaluate, report, and monitor students' achievement of the national and grade-level expectations, i.e., the essential knowledge, skills, values and attitudes they are expected to master and demonstrate proficiency on. Teachers should use the information and examples on standards-based assessment to plan, assess, record, evaluate, report and monitor students' performance in relation to the learning standards.

## Make informed Judgments About Students' Learning and Progress Towards Meeting Learning Standards

Teachers should use the teacher guide to effectively evaluate students' performance and use the evidence to help students to continuously improve their learning as well as their classroom practice.

It is important that teachers evaluate the performance of students in relation to the performance standards and progressively the grade-level benchmarks and content standards to make informed judgments and decisions about the quality of their work and their progress towards meeting the content standards or components of the standards. Evaluation should not focus on only one aspect of students' performance. It should aim to provide a complete picture of each student's performance. The context, inputs, processes, including teaching and learning processes, and the outcomes should be evaluated to make an informed judgment about each student's performance, Teachers should identify the causal factors for poor performance, gaps in students learning, gaps in teaching, teaching and learning resource constraints, and general attitude towards learning. Evidence-based decisions can then be made regarding the interventions for closing the gaps to allow students to make the required progress towards meeting grade-level and national expectations.

## Prepare Students' Performance Reports

Reporting of students' performance and progress towards the attainment of learning standards is an essential part of SBC assessment. Results of students' performance should be communicated to particularly the students and their parents to keep them informed of students' academic achievements and learning challenges as well as what needs to be done to enable the students' make positive progress towards meeting the proficiency standards and achieve the desired level of education quality. Teachers should use the information on the reporting of students' assessment results and the templates provided to report the results of students' learning.

## Monitor Students' Progress Towards Meeting the National Content Standards and Grade-Level Benchmarks

Monitoring of student's progress towards the attainment of learning standards is an essential component of standards-based assessment. It is an evidence-based process that involves the use of data from students' performance assessments to make informed judgements about students' learning and proficiency on the learning standards or their components, identify gaps in students' learning and the causal factors, set clear learning improvement targets, and develop effective evidence-based strategies (including preplanning and re-teaching of topics), set clear timeframes, and identify measures for measuring students' progress towards achieving the learning targets.

Teachers should use the teacher guide to help them use data from students' performance assessments to identify individual students' learning weaknesses and develop interventions, in collaboration with each student and his/her parents or guardians, to address the weaknesses and monitor their progress towards meeting the agreed learning goals.

## Develop additional Benchmarks

Teachers can develop additional benchmarks using the examples in the teacher guide to meet the learning needs of their students and local communities. However, these benchmarks will not be nationally assessed as these are not comparable. They are not allowed to set their own content standards or manipulate the existing ones. The setting of national content standards is done at the national level to ensure that required learning standards are maintained and monitored to sustain the required level of education quality.

## Avoid Standardisation

**The implementation of Science curriculum must not be standardised.**

SBC does not mean that the content, lesson objectives, teaching and learning strategies, and assessment are standardised. This is a misconception and any attempt to standardise the components of curriculum without due consideration of the teaching and learning contexts, children's backgrounds and experiences, and different abilities and learning styles of children will be counterproductive. It will hinder students from achieving the expected proficiency standards and hence, high academic standards and the desired level of education quality. That is, they should not be applied across all contexts and with all students, without considering the educational needs and the characteristics of each context. Teachers must use innovative, creative, culturally relevant, and differentiated teaching and learning approaches to teach the curriculum and enable their students to achieve the national content standards and grade-level benchmarks. And enable all students to experience success in learning the curriculum and achieve high academic standards.

What is provided in the syllabus and teacher guide are not fixed and can be changed. Teachers should use the information and examples provided in the syllabus and the teacher guide to guide them to develop, select, and use grade, context, and learner appropriate content, learning objectives, teaching and learning strategies, and performance assessment and standards. SBC is evidence-based hence decisions about the content, learning outcomes, teaching and learning strategies, students' performance, and learning interventions should be based on evidence. Teaching and learning should be continuously improved and effectively targeted using evidence from students' assessment and other sources.

# Syllabus and Teacher Guide Alignment

A teacher guide is a framework that describes how to translate the content standards and benchmarks (learning standards) outlined in the syllabus into units and topics, learning objectives, lesson plans, teaching and learning strategies, performance assessment, and measures for measuring students' performance (performance standards). It expands the content overview and describes how this content identified in the content standards and their components (essential KSVAs) can be translated into meaningful and evidence-based teaching topics and learning objectives for lesson planning, instruction and assessment. It also describes and provides examples of how to evaluate and report on students' attainment of the learning standards, and use evidence from the assessment of students' performance to develop evidence-based interventions to assist students who are making slow progress towards meeting the expected proficiency levels to improve their performance.

Grade 10 Science comprises of the Syllabus and Teacher Guide. These two documents are closely aligned, complimentary and mutually beneficial.
They are the essential focal points for teaching and learning the essential Science knowledge, skills, values and attitudes.

| Syllabus and Teacher Guide Alignment | |
|---|---|
| **Syllabus** | **Teacher Guide** |
| Outlines the ultimate aim and goals, and what to teach and why teach it | Describes how to plan, teach, and assess students' performance |
| • Overarching and SBC principles<br>• Content overview<br>• Core curriculum<br>• Essential knowledge, skills, values and attitudes<br>• Strands and units<br>• Evidence outcomes<br>• Content standards and grade-level benchmarks<br>• Overview of assessment, evaluation, and Reporting | • Determine topics for lesson planning,<br>• instruction and assessment<br>• Formulate learning objectives<br>• Plan SBC lesson plans<br>• Select teaching and learning strategies<br>• Implement SBC assessment and<br>• evaluation<br>• Implement SBC reporting and monitoring |

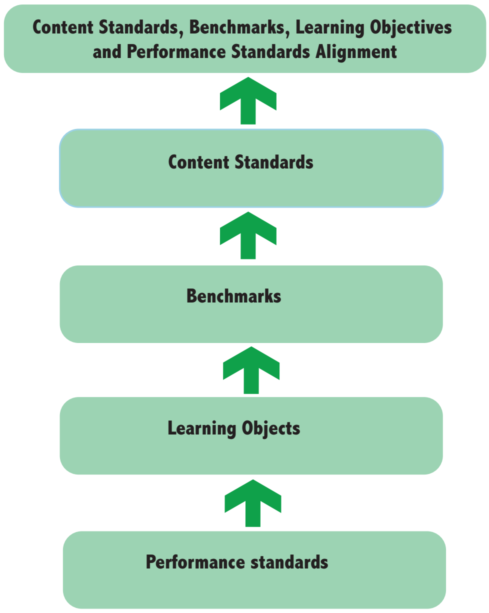
The syllabus outlines the ultimate aim and goals of SBE and SBC, what is to be taught and why it should be learned by students, the underlying principles and articulates the learning and proficiency standards that all students are expected to attain. On the other hand, the teacher guide expands on what is outlined in the syllabus by describing the approaches or the how of planning, teaching, learning, and assessing the content so that the intended learning outcomes are achieved.

This teacher guide should be used in conjunction with the syllabus. Teachers should use these documents when planning, teaching and assessing science content.

Teachers will extract information from the syllabus (e.g., content standards and grade-level benchmarks) for lesson planning, instruction and is for measuring students' attainment a content standard as well as progress to the next grade of schooling.

## Learning and Performance Standards Alignment

Content Standards, Benchmarks, Learning Objectives, and Performance Standards are very closely linked and aligned (see figure 3). There is a close linear relationship between these standards. Students' performance on a significant aspect of a benchmark (KSVA) is measured against a set of performance standards or criteria to determine their level of proficiency using performance assessment. Using the evidence from the performance assessment, individual student's proficiency on the aspect of the benchmark assessed and progression towards meeting the benchmark and hence the content standard are then determined.




Effective alignment of these learning standards and all the other components of PNG SBE and SBC (ultimate aim and goals, overarching, SBC and subject-based principles, core curriculum, STEAM, and cognitive, high level, and 21st Century skills) is not only critical but is also key to the achievement of high academic standards by all students and the intended level of education quality. It is essential that teachers know and can do standards alignment when planning, teaching, and assessing students' performance so that they can effectively guide their students towards meeting the grade-level benchmarks (grade expectations) and subsequently the content standards (national expectations).

# Learning and Performance Standards

Standards-Based Education (SBE) and SBE are underpinned by the notion of quality. Standards define the expected level of education quality that all students should achieve at a particular point in their schooling. Students' progression and achievement of education standard (s) are measured using performance standards or criteria to determine their demonstration or performance on significant aspects of the standards and therefore their levels of proficiency or competency. When they are judged to have attained proficiency on a content standard or benchmark or components of these standards, they are then deemed to have met the standard(s) that is, achieved the intend level of education quality.

Content standards, benchmarks, and learning objectives are called learning standards while performance and proficiency standards (evidence outcomes) can be categorised as performance standards. These standards are used to measure students' performance, proficiency, progression and achievement of the desired level of education quality. Teachers are expected to understand and use these standards for lesson planning, instruction and assessment

## Content Standards

Content standards are evidence-based, rigorous and comparable regionally and globally. They have been formulated to target critical social, economic, political, cultural, environment, and employable skills gaps identified from a situational analysis. They were developed using examples and experiences from other countries and best practice, and contextualized to PNG contexts.

Content standards describe what (**content - knowledge, skills, values, and attitudes**) all students are expected to know and do (how well students must learn and apply what is set out in the content standards) at each grade-level before proceeding to the next grade. These standards are set at the national level and thus cannot be edited or changed by anyone except the National Subject-Based Standards Councils. Content Standards:

- are evidenced-based;
- are rigorous and comparable to regional and global standards;
- are set at the national level;
- state or describe the expected levels of quality or achievement;
- are clear, measurable and attainable;
- are linked to and aligned with the ultimate aim and goals of SBE and SBC and overarching and SBC principles;
- delineate what matters, provide clear expectations of what students should progressively learn and achieve in school, and guide lesson planning, instruction, assessment;
- comprise knowledge, skills, values, and attitudes that are the basis for quality education;
- provide teachers a clear basis for planning, teaching, and assessing lessons;
- provide provinces, districts, and schools with a clear focus on how to develop and organise their instruction and assessment programs as well as the content that they will include in their curriculum.

## Benchmarks

Benchmarks are derived from the content standards and benchmarked at the grade-level. Benchmarks are specific statements of what students should know (i.e., essential knowledge, skills, values or attitudes) at a specific grade-level or school level. They provide the basis for measuring students' attainment of a content standard as well as progress to the next grade of schooling.

Grade-level benchmarks:

- are evidenced-based;
- are rigorous and comparable to regional and global standards;
- are set at the grade level;
- are linked to the national content standards;
- are clear, measurable, observable and attainable;
- articulate grade level expectations of what students are able to demonstrate to indicate that they are making progress towards attaining the national content standards;
- provide teachers a clear basis for planning, teaching, and assessing lessons;
- state clearly what students should do with what they have learned at the end of each school-level;
- enable students' progress towards the attainment of national content standards to be measured, and
- enable PNG students' performance to be compared with the performance of PNG students with students in other countries.

## Approach for Setting National Content Standards and Grade-Level Benchmarks

Strands → Content Standards → Grade -Level Benchmark

### *Development of Additional Benchmarks*

Teachers should develop additional benchmarks to meet the learning needs of their students. They should engage their students to learn about local, provincial, national and global issues that have not been catered for in the grade-level benchmarks but are important and can enhance students' understanding and application of the content. However, it is important to note that these benchmarks will not be nationally examined as they are not comparable. Only the benchmarks developed at the national level will be tested. This does not mean that teachers should not develop additional benchmarks. An innovative, reflect, creative and reflexive teacher will continuously reflect on his/her classroom practice and use evidence to provide challenging, relevant, and enjoyable learning opportunities for his/her students to build on the national expectations for students. Teachers should follow the following process when developing additional grade-level benchmarks

**Benchmark Development Process**

Determine what needs to be taught (essential knowledge, skills, values and attitudes) → Determine if what is to be taught will contribute towards the achievement of the national content standard → Formulate benchmarks following the sequence of benchmarks already developed for the content standard

### *Learning Objectives*

Learning or instructional Objectives are precise statements of educational intent. They are formulated using a significant aspect or a topic derived from the benchmark, and is aligned with the educational goals, content standards, benchmarks, and performance standards. Learning objectives are stated in outcomes language that describes the products or behaviours that will be provided by students. They are stated in terms of measurable and observable student behaviour. For example, students will be able to identify all the main towns of PNG using a map.

### *Performance Standards*

Performance Standards are concrete statements of how well students must learn what is set out in the content standards, often called the **“be able to do”** of “what students should know and be able to do.” Performance standards are the indicators of quality that specify how competent a students’ demonstration or performance must be. They are explicit definitions of what students **must do to demonstrate proficiency or competency at a specific level on the content standards.** Performance standards:

- measure students’ performance and proficiency (using performance indicators) in the use of a specific knowledge, skill, value, or attitude in real life or related situations

- provide the basis (performance indicators) for evaluating, reporting and monitoring students’ level of proficiency in use of a specific knowledge, skills, value, or attitude

- are used to plan for individual instruction to help students not yet meeting expectations (desired level of mastery and proficiency) to make adequate progress towards the full attainment of benchmarks and content standards

- are used as the basis for measuring students’ progress towards meeting grade-level benchmarks and content standards

### *Proficiency Standards*

Proficiency standards describe what all students in a particular grade or school level can do at the end of a strand, or unit. These standards are sometimes called evidence outcomes because they indicate if students can actually apply or use what they have learnt in real life or similar situations. They are also categorized as benchmarks because that is what all students are expected to do before exiting a grade or are deemed ready for the next grade.

# Core Curriculum

A core set of common learnings (knowledge, skills, values, and attitudes) are integrated into the content standards and grade-level benchmarks for all subjects. This is to equip all students with the most essential and in-demand knowledge, skills, and dispositions they will need to be successful in modern/ postmodern work places, higher-education programs and to be productive, responsible, considerate, and harmonious citizens. Common set of learnings are spirally sequenced from Preparatory - Grade 12 to deepen the scope and increase the level of difficulty in the learning activities so that what is learned is reinforced at different grade levels.

The core curriculum includes:

- cognitive (thinking) skills (Refer to the syllabus for a list of these skills);
- reasoning, decision-making and problem-solving skills
- high level thinking skills (analysis, synthesis and evaluation skills);
- 21st Century skills (Refer to illustrative list in the Appendix);
- reading, writing and communication skills;
- STEAM principles and skills;
- essential values and attitudes (Core personal and social values, and sustaining values), and
- spiritual values and virtues

The essential knowledge, skills, values and attitudes comprising the core curriculum are interwoven and provide an essential and holistic framework for preparing all students for careers, higher education and citizenship.

All teachers are expected to include the core learnings in their lesson planning, teaching, and assessment of students in all their lessons. They are expected to foster, promote and model the essential values and attitudes as well as the spiritual values and virtues in their conduct, practice, appearance, and their relationships and in their professional and personal lives. In addition, teachers are expected to mentor, mould and shape each student to evolve and possess the qualities envisioned by society.

Core values and attitudes must not be taught in the classroom only; they must also be demonstrated by students in real life or related situations inside and outside of the classroom, at home, and in everyday life. Likewise, they must be promoted, fostered and modeled by the school community and its stakeholders, especially parents. A whole of school approach to values and attitudes teaching, promoting and modeling is critical to students and the whole school community internalising the core values and attitudes and making them habitual in their work and school place, and in everyday life. Be it work values, relationship values, peace values, health values, personal and social values, or religious values, teachers should give equal prominence to all common learnings in their lesson planning, teaching, assessment, and learning interventions. Common learnings must be at the heart of all teaching and extracurricularprograms and activities.

# Science, Technology, Engineering, Arts and Mathematics

STEAM education is an integrated, multidisciplinary approach to learning that uses science, technology, engineering, arts and mathematics as the basis for inquiring about how STEAM has and continues to change and impact the social, political, economic, cultural and environmental contexts and identifying and solving authentic (real life) natural and physical environment problems by integrating STEAM-based principles, cognitive, high level and 21st Century skills and processes, and values and attitudes.

Science is focused on both goals of STEAM rather than just the goal of problem-solving. This is to ensure that all students are provided opportunities to learn, integrate, and demonstrate proficiency on all essential STEAM principles, processes, skills, values and attitudes to prepare them for careers, higher education and citizenship.

## Objectives

Students will be able to:

**(i)** examine and use evidence to draw conclusions about how STEAM has and continues to change the social, political, economic, cultural and environmental contexts.
**(ii)** Investigate and draw conclusions on the impact of STEAM solutions to problems on the social, political, economic, cultural and environmental contexts.
**(iii)** Identify and solve problems using STEAM principles, skills, concepts, ideas and process.
**(iv)** Identify, analyse and select the best solution to address a problem.
build prototypes or models of solutions to problems.
replicate a problem solution by building models and explaining how the problem was or could be solved.
**(v)** test and reflect on the best solution chosen to solve a problem.
collaborate with others on a problem and provide a report on the process of problem solving used to solve the problem.
**(vi)** use skills and processes learnt from lessons to work on and complete STEAM projects.
**(x)** demonstrate STEAM principles, skills, processes, concepts and ideas through simulation and modelling.
**(xi)** explain the significance of values and attitudes in problem-solving.

STEAM is a multidisciplinary and integrated approach to understanding how science, technology, engineering, arts and mathematics shape and are shaped by our material, intellectual, cultural, economic, social, political and environmental contexts. And for teaching students the essential in demand cognitive, high level and 21st Century skills, values and attitudes, and empower them to effectively use these skills and predispositions to identify and solve problems relating to the natural and physical environments as well as the impact of STEAM-based solutions on human existence and livelihoods, and on the social, political, economic, cultural, and environmental systems.

STEAM disciplines have and continue to shape the way we perceive knowledge and reality, think and act, our values, attitudes, and behaviours, and the way we relate to each other and the environment. Most of the things we enjoy and consume are developed using STEAM principles, skills, process, concepts and ideas. Things humans used and enjoyed in the past and at present are developed by scientists, technologists, engineers, artists and mathematicians to address particular human needs and wants. Overtime, more needs were identified and more products were developed to meet the ever changing and evolving human needs. What is produced and used is continuously reflected upon, evaluated, redesigned, and improved to make it more advanced, multipurpose, fit for purpose, and targeted towards not only improving the prevailing social, political, economic, cultural and environmental conditions but also to effectively respond to the evolving and changing dynamics of human needs and wants. And, at the same time, solutions to human problems and needs are being investigated and designed to address problems that are yet to be addressed and concurred. This is an evolving and ongoing problem-solving process that integrates cognitive, high level, and 21st Century skills, and appropriate values and attitudes.

STEAM is a significant framework and focal point for teaching and guiding students to learn, master and use a broad range of skills and processes required to meet the skills demands of PNG and the 21st Century. The skills that students will learn will reflect the demands that will be placed upon them in a complex, competitive, knowledge-based, information-age, technology-driven economy and society. These skills include cognitive (critical, synthetic, creative, reasoning, decision-making, and problem-solving) skills, high level (analysis, synthesis and evaluation) skills and 21st Century skills (see Appendix 4). Knowledge-based, information, and technology driven economies require knowledge workers not technicians. Knowledge workers are lifelong learners, are problem solvers, innovators, creators, critical and creative thinkers, reflective practitioners, researchers (knowledge producers rather than knowledge consumers), solutions seekers, outcomes oriented, evidence-based decision makers, and enablers of improved and better outcomes for all.

STEAM focuses on the skills and processes of problem solving. These skills and processes are at the heart of the STEAM movement and approach to not only problem solving and providing evidence-based solutions but also the development and use of other essential cognitive, high level and 21st Century skills. These skills are intertwined and used simultaneously to gain a broader understanding of the problems to enable creative, innovative, contextually relevant, and best solutions to be developed and implemented to solve the problems and attain the desired outcomes. It is assumed that by teaching students STEAM-based problem-solving skills and providing learning opportunities inside and outside the classroom will motivate more of them to pursue careers and academic programs in STEAM related fields thus, closing the skills gaps and providing a pool of cadre of workers required by technology, engineering, science, and mathematics-oriented industries.

## STEAM Problem-Solving Processes

Problem-solving involves the use of problem-solving methods and processes to identify and define a problem, gather information to understand its causes, draw conclusions, and use the evidence to design and implement solutions to address it. Even though there are many different problem-solving methods and approaches, they share some of the steps of problem-solving, such as;

- identifying the problem,
- understanding the problem by collecting data,
- analyse and interpret the data,
- draw conclusions,
- use data to consider possible solutions,
- select the best solution,
- test the effectiveness of the solution by trialling and evaluating it, and
- review and improve the solution.

STEAM problem solving processes go from simple and technical to advance and knowledge-based processes. However, regardless of the type of process used, students should be provided opportunities to learn the essential principles and processes of problem solving and, more significantly, to design and create a product that addressed a real problem and meets a human need.

The following are some of the STEAM problem solving processes.

### 1. Engineering and Technology Problem Solving Methods and Approaches

Engineering and technology problem-solving methods are used to identify and solve problems relating to the physical world using the design process. The following are some of the methods and approaches used to solve engineering and technology related problems.

***Parts Substitution***

It is the most basic of the problem-solving methods. It simply requires the parts to be substituted until the problem is solved.

***Diagnostics***

After identifying a problem, the technician would run tests to pinpoint the fault. The test results would be used either as a guide for further testing or for replacement of a part, which also need to be tested. This process continues until the solution is found and the device is operating properly.

***Troubleshooting***

Troubleshooting is a form of problem solving, often applied to repair failed products or processes.

### *Reverse Engineering*

Reverse engineering is the process of discovering the technological principles underlying the design of a device by taking the device apart, or carefully tracing its workings or its circuitry. It is useful when students are attempting to build something for which they have no formal drawings or schematics.

### *Divide and Conquer*

Divide and conquer is the technique of breaking down a problem into sub-problems, then breaking the sub-problems down even further until each of them is simple enough to be solved. Divide and conquer may be applied to all groups of students to tackle sub-problems of a larger problem, or when a problem is so large that its solution cannot be visualised without breaking it down into smaller components.

### *Extreme Cases*

Considering "extreme cases" – envisioning the problem in a greatly exaggerated or greatly simplified form, or testing using extreme condition – can often help to pinpoint a problem. An example of the extreme-case method is purposely inputting an extremely high number to test a computer program.

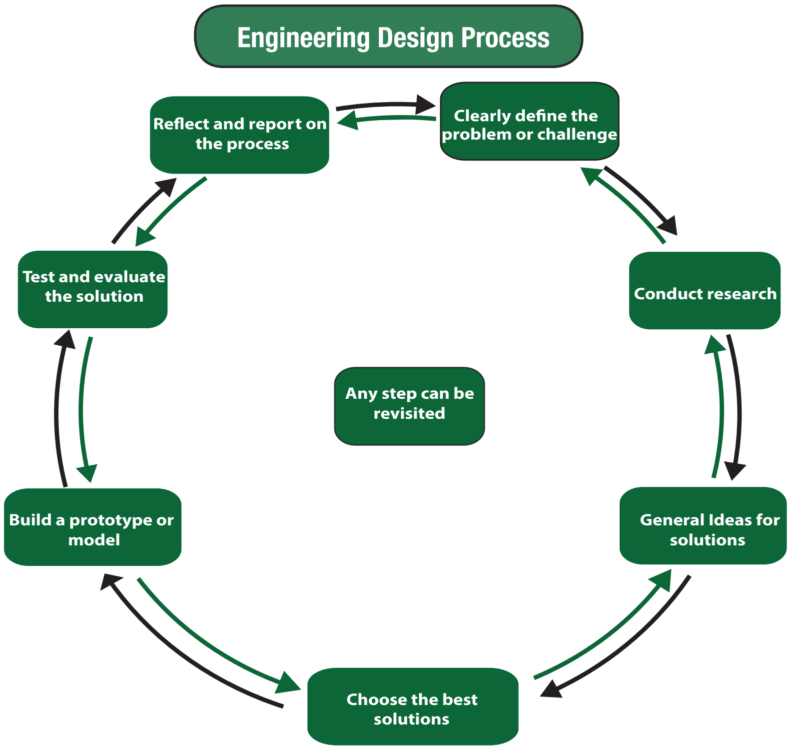
### *Trial and Error*

The trial and error method involve trying different approaches until a solution is found. It is often used as a last resort when other methods have been exhausted.

## 2. Engineering Design Process

Technological fields use the engineering design process to identify and define the problem or challenge, investigate the problem, collect and analyse data, and use the data to formulate potential solutions to the problem, analyse each of the solutions in terms of its strengths and weaknesses, and choose the best solution to solve the problem. It is an open-ended problem-solving process that involves the full planning and development of products or services to meet identified needs. It involves a sequence of steps such as the following:

1. Analyse the context and background, and clearly define the problem.
2. Conduct research to determine design criteria, financial or other constraints, and availability of materials.
3. Generate ideas for potential solutions, using processes such as brainstorming and sketching.
4. Choose the best solution.
5. Build a prototype or model.
6. Test and evaluate the solution.
7. Repeat steps as necessary to modify the design or correct faults.
8. Reflect and report on the process.




## STEAM-Based Lesson planning

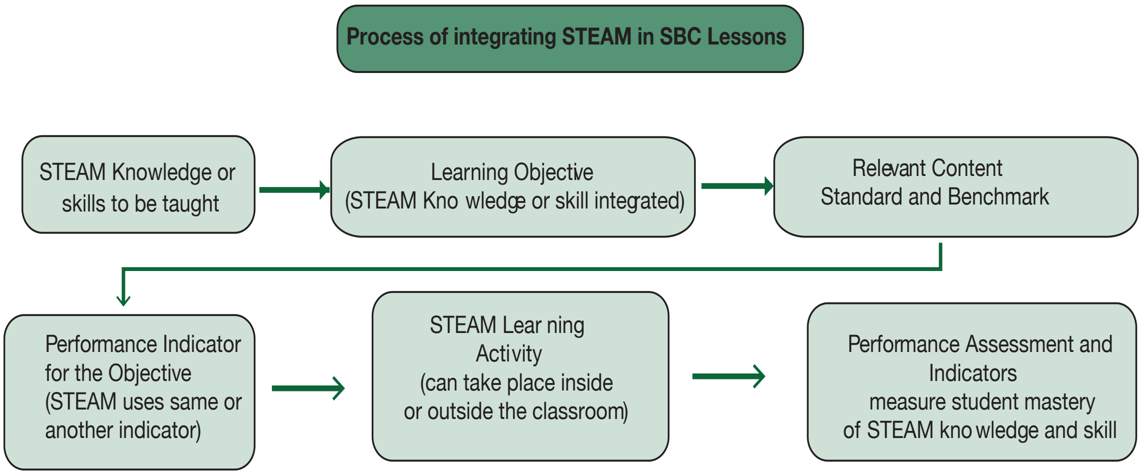
Effective STEAM lesson planning is key to the achievement of expected STEAM outcomes. STEAM skills can be planed and taught using separate STEAM-based lesson plans or integrated into the standards-based lesson plans. To effectively do this, teachers should know how to write effective standards and STEAM-based lesson plans.

An example of a STEAM-based lesson plan is provided in the Appendix.
Teachers should use this to guide them to integrate STEAM content and teaching, learning and assessment strategies into their standards-based lesson plans.

Knowing how to integrate STEAM problem-solving skills, principles, values and attitudes as well as STEAM teaching, learning, and assessment strategies into standards-based lesson plans is essential for achieving the desired STEAM learning outcomes. When integrating STEAM problem-solving skills into the standards-based lesson plans, teachers should ensure that these skills are not only effectively aligned to the learning objective and performance standards, they must also be effectively taught and assessed.

Teachers are expected to integrate the essential STEAM principles, processes, skills, values and attitudes described in the grade 12 benchmarks when Teachers are expected to integrate the essential STEAM principles, processes, skills, values and attitudes described in the grade 11 benchmarks when formulating their standards-based lesson plans. Opportunities should be provided inside and outside of the classroom for students to learn, explore, model and apply what they learn in real life or related situations. These learning experiences will enable students to develop a deeper understanding of STEAM principles, processes, skills, values and attitudes and appreciate their application in real life to solve problems.

## Process for Integrating STEAM Principles and Problem-Solving Skills into Standards-Based Lessons




Teachers should follow the steps given below when integrating STEAM problem-solving principles and skills into their standards-based lesson plans.

**Step 1:** Identify the STEAM knowledge or skill to be taught (From the table of KSVAs for each content standard and benchmark). This could already be captured in the learning objective stated in the standards-based lesson plan.

**Step 2:** Develop and include a performance standard or indicator for measuring student mastery of the STEAM knowledge or skill *(e.g.* level of acceptable competency or proficiency) if this is different from the one already stated in the lesson plan.

**Step 3:** Develop student learning activity (An activity that will provide students the opportunity to apply the STEAM knowledge or skill specified by the learning objective and appropriate statement of the standards). Activity can take place inside or outside of the classroom, and during or after school hours.

**Step 4:** Develop and use performance descriptors (standards or indicators) to analyse students' STEAM related behaviours and products (results or outcomes), which provide evidence that the student has acquired and mastered the knowledge or skill of the learning objective specified by the indicator (s) of the standard (s).

## STEAM Teaching Strategies

STEAM education takes place in both formal and informal classroom settings. It takes place during and after school hours. It is a continuous process of inquiry, data analysis, making decisions about interventions, and implementing and monitoring interventions for improvements.

There are a variety of STEAM teaching strategies. However, teaching strategies selected must enable teachers to guide students to use the engineering and artistic design processes to identify and solve natural and physical environment problems by designing prototypes and testing and refining them to effectively mitigate the problems identified. The following are some of the strategies that could be used to utilise the STEAM approach to solve problems and coming up with technological solutions.

- *Inquiry-Based Learning*
- *Problem-Based Learning*
- *Project-based learning,*
- *Collaborative Learning*

Collaborative learning involves individuals from different STEAM disciplines and expertise in a variety of STEAM problem solving approaches working together and sharing their expertise and experiences to inquire into and solve a problem.

Teachers should plan to provide students opportunities to work in collaboration and partnership with experts and practitioners engaged in STEAM related careers or disciplines to learn first-hand about how STEAM related skills, processes, concepts, and ideas are applied in real life to solve problems created by natural and physical environments. Collaborative learning experiences can be provided after school or during school holidays to enable students to work with STEAM experts and practitioners to inquiry and solve problems by developing creative, innovative and sustainable solutions. Providing real life experiences and lessons, e.g., by involving students to actually solve a scientific, technological, engineering, or mathematical, or Arts problem, would probably spark their interest in a STEAM career path. Developing STEAM partnerships with external stakeholders e.g., high education institutions, private sector, research and development institutions, and volunteer and community development organizations can enhance students' learning and application of STEAM problem solving principles and skills.

*Some examples of STEAM-related partnership experiences may include:*

- *Participatory Learning*
- *Group-Based Learning*
- *Task Oriented Learning*
- *Action Learning*
- *Experiential Learning*
- *Modelling*
- *Simulation*

## STEAM Learning Strategies

Teachers should include in their lesson plans STEAM learning activities. These activities should be aligned to principle or a skill planned for students to learn and demonstrate proficiency at the end of the lesson to expose students to STEAM and giving them opportunities to explore STEAM-related concepts, they will develop a passion for it and, hopefully, pursue a job in a STEAM field. Providing real life experiences and lessons, e.g., by involving students to actually solve a scientific, technological, engineering, or mathematical, or arts problem, would probably spark their interest in a STEAM career path. This is the theory behind STEAM education.

## STEAM-Based Assessment

STEAM-based assessment is closely linked to standards-based assessment where assessment is used to assess students' level of competency or proficiency of a specific knowledge, skill, value, or attitude taught using a set of performance standards (indicators or descriptors). The link also includes the main components such as the purpose, the assessment principles and assessment strategies and tools.

In STEAM-based assessment, assessments are designed for what students should know and be able to do. In STEAM learning, students are assessed in a variety of ways including portfolios, project/problem-based assessments, backwards design, authentic assessments, or other student-centered approaches.

When planning and designing the assessment, teachers should consider the authenticity of the assessment by designing an assessment that relates to a real world task or discipline specific attributes such as simulation, role play, placement assessment, live projects and debates. These tasks should make the activity meaningful to the student, and therefore be motivating as well as developing employability skills and discipline specific attributes.

## STEAM Learning Strategies

Teachers should include in their lesson plans STEAM learning activities. These activities should be aligned to principle or a skill planned for students to learn and demonstrate proficiency at the end of the lesson to expose students to STEAM and giving them opportunities to explore STEAM-related concepts, they will develop a passion for it and, hopefully, pursue a job in a STEAM field. Providing real life experiences and lessons, e.g., by involving students to actually solve a scientific, technological, engineering, or mathematical, or arts problem, would probably spark their interest in a STEAM career path. This is the theory behind STEAM education.

## STEAM-Based Assessment

STEAM-based assessment is closely linked to standards-based assessment where assessment is used to assess students' level of competency or proficiency of a specific knowledge, skill, value, or attitude taught using a set of performance standards (indicators or descriptors). The link also includes the main components such as the purpose, the assessment principles and assessment strategies and tools.

In STEAM-based assessment, assessments are designed for what students should know and be able to do. In STEAM learning, students are assessed in a variety of ways including portfolios, project/problem-based assessments, backwards design, authentic assessments, or other student-centered approaches.

When planning and designing the assessment, teachers should consider the authenticity of the assessment by designing an assessment that relates to a real world task or discipline specific attributes such as simulation, role play, placement assessment, live projects and debates. These tasks should make the activity meaningful to the student, and therefore be motivating as well as developing employability skills and discipline specific attributes.

## Effective STEAM-Based Assessment Strategies

The following are the six assessment tools and strategies shown to impact teaching and learning as well as help teachers foster a 21st Century learning environment in their classrooms.

1. *Rubrics*
2. *Performance-Based Assessments (PBAs)*
3. *Portfolios*
4. *Student self-assessment*
5. *Peer-assessment*
6. *Student Response Systems(SRS).*

Although the list does not include all innovative assessment strategies, it includes what we think are the most common strategies, and ones that may be particularly relevant to the educational context of developing countries in this 21st Century. Many of the assessment strategies currently in use fit under one or more of the categories discussed. Furthermore, it is important to note that these strategies also connect in a variety of ways.

*1. Rubrics*

Rubrics are both a tool to measure students' knowledge and ability as well as an assessment strategy. A rubric allows teachers to measure certain skills and abilities not measurable by standardized testing systems that assess discrete knowledge at a fixed moment in time. Rubrics are also frequently used as part of other assessment strategies including; portfolios, performances, projects, peer-review and self-assessment which are also elaborated in this section.

*2. Performance-Based Assessments*

Performance-Based Assessments (PBA), also known as project-based or authentic assessments, are generally used as a summative evaluation strategy to capture not only what students know about a topic, but if they have the skills to apply that knowledge in a "real-world" situation. By asking them to create an end product. PBA pushes students to synthesize their knowledge and apply their skills to a potentially unfamiliar set of circumstances that is likely to occur beyond the confines of a controlled classroom setting.

The implementation of performance-based assessment strategies can also impact other instructional strategies in the classroom.

*3. Portfolio Assessment*

Portfolios are a collection of student work gathered over time that is primarily used as a summative evaluation method. The most salient characteristic of the portfolio assessment is that rather than being a snapshot of a student's knowledge at one point in time (like a single standardized test), it highlights student effort, development, and achievement over a period of time; portfolios measure a student's ability to apply knowledge rather than simply regurgitate. They are considered both student-centred and authentic assessments of learning.

*4. Self-assessment*

While the previous assessment tools and strategies listed in this report generally function as summative approaches, self-assessment is generally viewed as a formative strategy, rather than one used to determine a student's final grade. Its main purpose is for students to identify their own strengths and weakness and to work to make improvements to meet specific criteria. Self-assessment occurs when students judge their own work to improve performance as they identify discrepancies between current and desired performance". In this way, self-assessment aligns well with standards-based education because it provides clear targets and specific criteria against which students or teachers can measure learning.

Self-assessment is used to promote self-regulation, to help students reflect on their progress and to inform revisions and improvements on a project or paper. In order for self-assessment to be truly effective four conditions must be in place: the self-assessment criteria is negotiated between teachers and students, students are taught how to apply the criteria, students receive feedback on their self-assessments and teachers help students use assessment data to develop an action plan.

*5. Peer assessment*

Peer assessment, much like self-assessment, is a formative assessment strategy that gives students a key role in evaluating learning. Peer assessment approaches can vary greatly but, essentially, it is a process for learners to consider and give feedback to other learners about the quality or value of their work. Peer assessments can be used for variety of products like papers, presentations, projects, or other skilled behaviours. Peer assessment is understood as more than only a grading procedure and is also envisioned as teaching strategy since engaging in the process develops both the assessor and assessee's skills and knowledge.

# Curriculum Integration

## What is Curriculum Integration?

Curriculum integration is making connections in learning across the curriculum. The ultimate aim of curriculum integration is to act as a bridge to increase students' achievement and engage in relevant curriculum. (Susan M. Drake and Rebecca C. Burns)

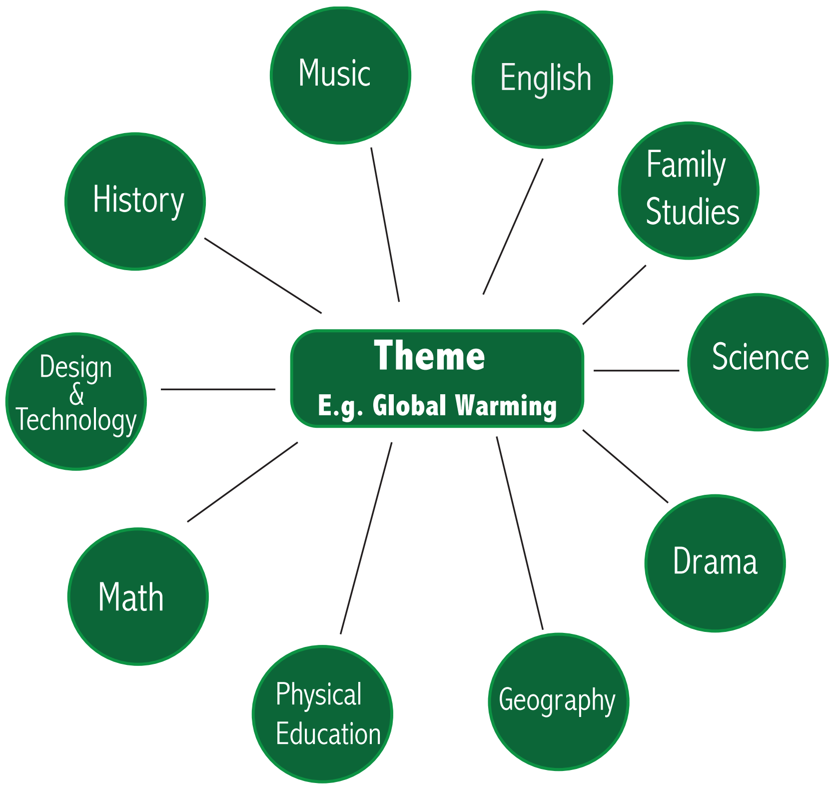
Teachers must develop intriguing curriculum by going beyond the traditional teaching of content based or fragmented teaching to one who is knowledge based and who should be perceived as a 21st Century innovative educator. Curriculum integration is a holistic approach to learning thus curriculum integration in PNG SBC will have to equip students with the essential knowledge, skills, values and attitudes that are deemed 21st Century.

There are three approaches that PNG SBC will engage to foster conducive learning for all its children whereby they all can demonstrate proficiency at any point of exit. Adapting these approaches will have an immense impact on the lives of these children thus they can be able to see themselves as catalyst of change for a competitive PNG. Not only that but they will be comparable to the world standards and as global citizens.

Engaging these three approaches in our curriculum will surely sharpen the knowledge and ability of each child who will foresee themselves as assets through their achievements thus contribute meaningfully to their country. They themselves are the agents of change. Integrated learning will bear forth a generation of knowledge based populace who can solve problems and make proper decisions based on evidence. Thus, PNG can achieve its goals like the Medium Term Development Goals (MTDG) and aims such as the Vision 2050 for a happy, healthy and wealthy society whereby, all its citizens should have access and fair distribution to income, shelter, health, education and general good and services improving the general standard of living for PNG in the long run.

**1. (i) Multidisciplinary Approach**

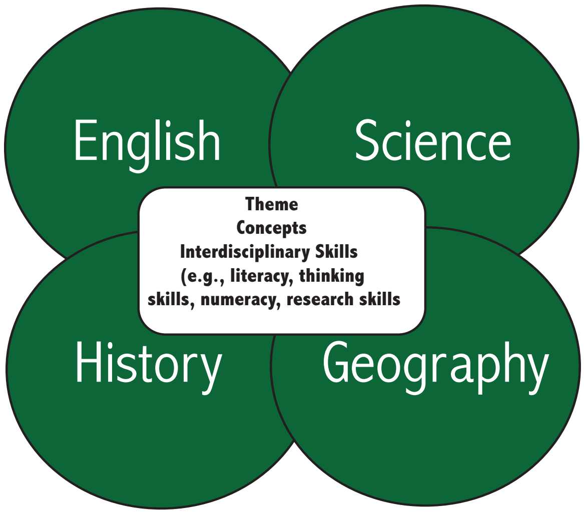
In this approach learning involves a theme or concept that will be taught right across all subject area of study by students. That is, content of a particular theme will be taught right across all subjects as shown in the diagram below. For instance, if the theme is global warming, subject areas create lessons or assessment as per their subjects around this theme. Social Science will address this issue, Science and all other subject likewise.




**(ii) Interdisciplinary Approach**

This approach addresses learning similarly to the multidisciplinary approach of integrated learning whereby learning takes place within the subject area. However, it is termed interdisciplinary in that the core curriculum of learning is interwoven into each subject under study by the students. For instance; in Social Science under the strand of geography students write essay on internal migration however, apart from addressing the issues of this topic, they are to apply the skill of writing text types in their essay such as argumentative essay, informative, explanatory, descriptive, expository and narrative essay while writing their essay. They must be able to capture the mechanics of English skills such as grammar, punctuation and so forth. Though these skills are studied under English they are considered as core skills that cut across all subjects under study. For example; if Science students were to write about human development in biology then the application of writing skills has to be captured by the students in their writing. It is not seen as an English skill but a standard essential skill all students must know and do regardless.

Therefore, essential knowledge, skills, values and attitudes comprising the core curriculum are interwoven and provide an essential and holistic framework for preparing all students for careers, higher education and citizenship in this learning.




**2. Interdisciplinary approach**

This approach involves teachers integrate sub disciplines within a subject area. For instance, within the subject Social Science, the strands (disciplines) of geography, environment, history, political science and environment will all be captured studying a particular content for Social Science. For example, under global warming, students will study the geographical aspects of global warming, environmental aspect of global warming and likewise for history, political science and economics. Thus, children are well aware of the issues surrounding global warming and can address it confidently at each level of learning.

**3. Trans disciplinary Approach**

In this approach learning goes beyond the subject area of study. Learning is organized around students' questions and concerns. That is, where there is a need for change to improve lives, students develop their own curriculum to effect these need. The trans-disciplinary approach addresses real-life situations thus giving the opportunity to students to attain real life skills. This learning approach is more to do with Project–Based Learning also referred to as problem-based learning or place- based learning.

The three steps to planning project based curriculum (Chard 1998).

1. Teachers and students select a topic of study based on student interests, curriculum standards, and local resources

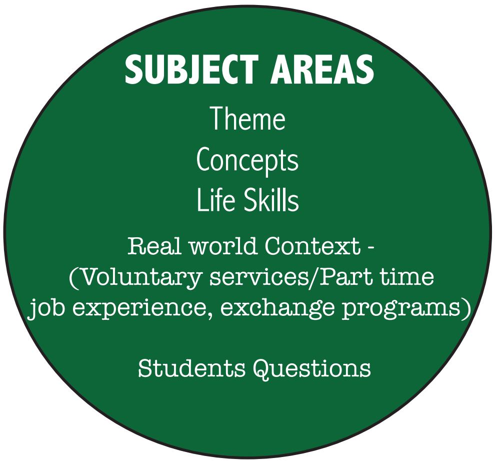
2. The teacher finds out what the students already know and helps them generate questions to explore. The teacher also provides resources for students and opportunities to work in the field.

3. Students share their work with others in a culminating activity. Students display the results of their exploration and review and evaluate the project.

For instance; students may come up with slogans for school programs such as 'Our culture – clean city for a healthier PNG'. The main aim could be to curb betel nut chewing in public areas especially around bus stops and local markets. Here, students draw up their own instructions and criteria for assessment which is; they have to clean the nearest bus stop or local market once a week throughout the year. They also design and create posters to educate the general public as their program continues. They can also involve the town council and media to assist them especially to carry out awareness.

Studies (Susan M. Drake and Rebecca C. Burns) have proven that Project based-programs have led to the following:

- Students go far beyond the minimum effort
- Make connections among different subject areas to answer open-ended questions
- Retain what they have learnt
- Apply learning to real-life problems
- Have fewer discipline problems
- Lower absenteeism (Curtis, 2002)




These integrated learning approaches will demand for teaches to be proactive in order to improve students learning and achievements. In order for PNG Standards-Based Curriculum to serve its purpose fully, these three approaches must be engaged for better learning for the children of Papua New Guinea now and in the future.

# Essential knowledge, Skills, Values, and Attitudes and Scientific Thinking Process

Students' level of proficiency and progression towards the attainment of content standards will depend on their mastery and application of essential knowledge, skills, values, and attitudes in real life or related situations. Provided here are examples of different types of knowledge, processes, skills, values, and attitudes that all students are expected to learn and master as they progress through the grades. These are expanded and deepen in scope and the level of difficulty and complexity are increased to enable students to study in-depth the subject content as they progress from one grade to the next.

These knowledge, skills, values and attitudes have been integrated into the content standards and benchmarks. They will also be integrated into the performance standards. Teachers are expected to plan and teach essential knowledge, skills, values and attitudes in their lessons, and assess students' performance and proficiency, and progression towards the attainment of content standards.

## Types of Knowledge

| **There are different types of knowledge. These include;** | |
|---|---|
| • Public and private (privileged) knowledge<br>• Specialised knowledge<br>• Good and bad knowledge<br>• Concepts, processes, ideas, skills, values, attitudes<br>• Theory and practice<br>• Fiction and non-fiction<br>• Traditional, modern, and postmodern knowledge | • Subject and discipline-based knowledge<br>• Lived experiences<br>• Evidence and assumptions<br>• Ethics and Morales<br>• Belief systems<br>• Facts and opinions<br>• Wisdom<br>• Research evidence and findings<br>• Solutions to problems |

## Types of Processes

| **There are different types of processes. These include;** | |
|---|---|
| • Problem-solving<br>• Logical reasoning<br>• Decision-making<br>• Reflection | • Cyclic processes<br>• Mapping (e.g. concept mapping)<br>• Modelling<br>• Simulating |
| **Science Inquiry processes include:**<br>• Gathering information<br>• Analysing information<br>• Evaluating information<br>• Making judgements<br>• Taking actions | |

## Types of Skills

There are different types of skills. These include:

**1. Cognitive (Thinking) Skills**

Thinking skills can be categorized into **critical thinking** and **creative thinking** skills.

### i. Critical Thinking Skills

| **A person who thinks critically always evaluates an idea in a systematic manner before accepting or rejecting it. Critical thinking skills include;** | |
|---|---|
| • Attributing<br>• Comparing and contrasting<br>• Grouping and classifying<br>• Sequencing<br>• Prioritising<br>• Analysing | • Detecting bias<br>• Evaluating<br>• Metacognition (Thinking about thinking)<br>• Making informed conclusions. |

### ii Creative Thinking Skills

| **A person who thinks creatively has a high level of imagination, able to generate original and innovative ideas, and able to modify ideas and products. Creative thinking skills include;** | |
|---|---|
| • Generating ideas<br>• Deconstruction and reconstruction<br>• Relating<br>• Making inferences<br>• Predicting<br>• Making generalisations<br>• Visualizing | • Synthesising<br>• Making hypothesis<br>• Making analogies<br>• Invention<br>• Transformation<br>• Modeling<br>• Simulating |

2. **Reasoning Skills** - Reason is a skill used in making a logical, just, and rational judgment.

3. **Decision-Making Skills** - Decision-making involves selection of the best solution from various alternatives based on specific criteria and evidence to achieve a specific aim.

4. **Problem Solving Skills** – These skills involve finding solutions to challenges or unfamiliar situations or unanticipated difficulties in a systematic manner.

### 5. Literacy Skills

A strong emphasis must be placed on various types of literacy, from financial to technological, from media to mathematical, from content to cultural. Literacy may be defined as the ability of an individual to use information to function in society, to achieve goals and to develop her or his knowledge and potential. Teachers emphasize certain aspects of literacy over others, depending on the nature of the content and skills they want students to learn.

| The following literacy skills are intended to be exemplary rather than definitive | |
|---|---|
| • Listens, read, write, and speak with comprehension and clarity<br>• Define and apply discipline-based conceptual vocabulary<br>• Describe people, places, and events, and the connections between and among them<br>• Arrange events in chronological sequence<br>• Differentiate fact from opinion<br>• Determine an author's purpose<br>• Determine and analyse similarities and differences<br>• Analyze cause and effect relationships<br>• Explore complex patterns, interactions and relationships<br>• Differentiate between and among various options | • Listens, read, write, and speak with comprehension and clarity<br>• Define and apply discipline-based conceptual vocabulary<br>• Describe people, places, and events, and the connections between and among them<br>• Arrange events in chronological sequence<br>• Differentiate fact from opinion<br>• Determine an author's purpose<br>• Determine and analyse similarities and differences<br>• Analyse cause and effect relationships<br>• Develop an ability to use and apply abstract principals<br>• Explore and/or observe, identify, and analyse how individuals and/or societies relate to one another |

**6. High Level Thinking Skills** - These skills include analysis, synthesis, and evaluation skills.

*i. Analysis Skills* – Analysis skills involve examining in detail and breaking information into parts by identifying motives or causes, underlying assumptions, hidden messages; making inferences and finding evidence to support generalisations, claims, and conclusions.

| Key Words | | | | |
|---|---|---|---|---|
| Analyse | Differences | Find | List | Similar to |
| Appraise | Discover | Focus | Motivate | Simplify |
| Arrange | Discriminate | Function | Omit | Take part in |
| Assumption | Discussion | Group | Order | Test for |
| Breakdown | Distinction | Highlight | Organize | Theme |
| Categorize | Distinguish | In-depth | Point out | |
| Cause & effect | Dissect | Inference | Research | |
| Choose | Divide | Inspect | See | |
| Classify | Establish | Isolate | Select | |
| Comparing | Examine | Investigate | Separate | |

***ii. Synthesis Skills*** – Synthesis skills involve changing or creating something new, compiling information together in a different way by combining elements in a new pattern proposing alternative solutions.

**iii. Evaluation Skills** – Evaluation skills involve justifying and presenting and defending opinions by making judgments about information, validity of ideas or quality of work based on set criteria.

## Types of Values

Personal engagement and civic engagement strategies help young people to acquire and apply skills and dispositions that will prepare them to become competent and responsible citizens.

### 1. Personal Values (importance, worth, usefulness, etc.)

| Core values | Sustaining values |
|---|---|
| • Sanctity of life<br>• Truth<br>• Aesthetics<br>• Honesty<br>• Human<br>• Dignity<br>• Rationality<br>• Creativity<br>• Courage<br>• Liberty<br>• Affectivity<br>• Individuality | • Self-esteem<br>• Self-reflection<br>• Self-discipline<br>• Self-cultivation<br>• Principal morality<br>• Self-determination<br>• Openness<br>• Independence<br>• Simplicity<br>• Integrity<br>• Enterprise<br>• Sensitivity<br>• Modesty<br>• Perseverance |

### 2. Social Values

| Core Values | Sustaining Values |
|---|---|
| • Equality<br>• Kindness<br>• Benevolence<br>• Love<br>• Freedom<br>• Common good<br>• Mutuality<br>• Justice<br>• Trust<br>• Interdependence<br>• Sustainability<br>• Betterment of human kind<br>• Empowerment | • Plurality<br>• Due process of law<br>• Democracy<br>• Freedom and liberty<br>• Common will<br>• Patriotism<br>• Tolerance<br>• Gender equity and social inclusion<br>• Equal opportunities<br>• Culture and civilisation<br>• Heritage<br>• Human rights and responsibilities<br>• Rationality<br>• Sense of belonging<br>• Solidarity<br>• Peace and harmony<br>• Safe and peaceful communities |

## Types of Attitudes

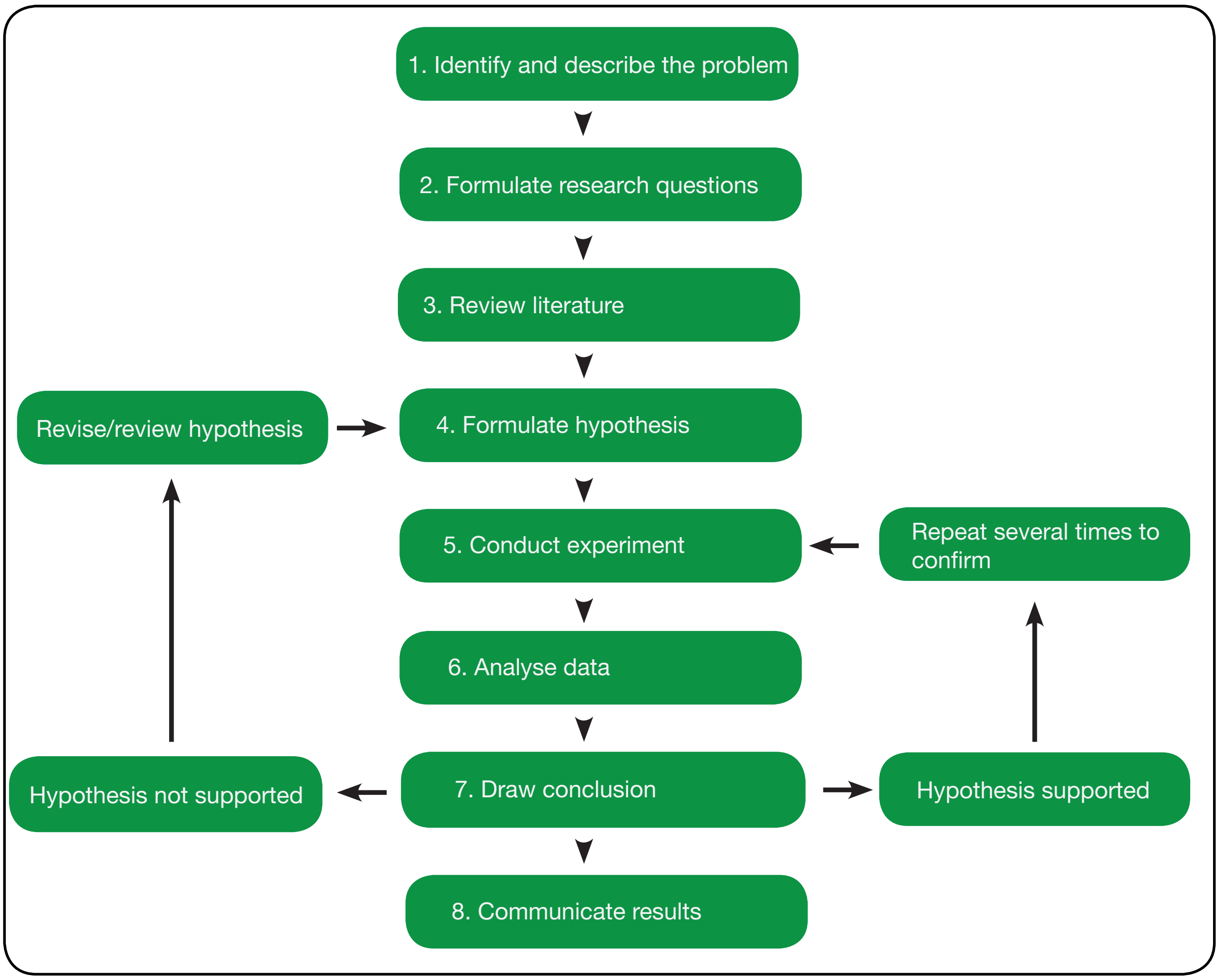
| Attitudes - Ways of thinking and behaving, points of view | |
|---|---|
| • Optimistic<br>• Participatory<br>• Critical<br>• Creative<br>• Appreciative<br>• Empathetic<br>• Caring and concern<br>• Positive<br>• Confident<br>• Cooperative | • Responsible<br>• Adaptable to change<br>• Open-minded<br>• Diligent<br>• With a desire to learn<br>• With respect for self, life, equality and excellence, evidence, fair play, rule of law, different ways of life, beliefs and opinions, and the environment. |

## Scientific Thinking Process

Scientists engage in scientific inquiry by following key science practices that enable them to understand the natural and physical world and answer questions about it. Science students must become proficient at these practices to develop an understanding of how the scientific enterprise is conducted. These practices include skills from daily life and school studies that students use in a systemic way to conduct scientific inquiry. There are six (6) basic science process skills science students have to master before they apply the science inquiry problem-solving approach. The process skills that are at the heart of the scientific inquiry and problem-solving process are:

- Observation
- Communication
- Classification
- Measurement
- Inference
- Prediction

The science practices are fundamental to all science disciplines. The eight (8) steps that are fundamental to scientific inquiry are outlined below. The steps in the process vary, depending on the purpose of the inquiry and the type of questions or hypothesis created.




The steps above should be taught and demonstrated by students separately and jointly before they implement the inquiry process. Students should be guided through every step of the process so that they can explain them, their importance and use the steps and the whole process proficiently to identify, investigate and solve problems. A brief explanations and examples of each step are provided below to assist teachers plan and teach each step.  Students should be provided with opportunities to practice and reflect on each step until they demonstrate the expected level of proficiency before moving on to the next step.

**Step 1: Identify and describe the problem**

Problems are identified mainly from observations and the use the five senses – smell, sight, sound, touch and taste. Students should be guided and provided opportunities to identify natural and physical environment problems using their five senses and describe what the problem is and its likely causes.

***Example:*** *Observation*

- When I turn on a flashlight using the on/off switch, light comes out of one end.

**Step 2: Formulate research question**

After the problem is identified and described, the question to be answered is then formulated. This question will guide the scientist in conducting research and experiments.

•

***Example:*** *Question*

- What makes light comes out of a flash light when I turn it on?

**Step 3: Review literature**

It is more likely that the research problem and question have already been investigated and reported by someone. Therefore, after asking the question, the scientist spends some time reading and reviewing papers and books on past research and discussions to learn more about the problem and the question ask to prepare her for his own research. Conducting literature review helps the scientist to better understand his/her research problem, refine the research question and decide on experiment/research approach before the experiment is conducted.

***Example:*** *Literature review*

- The scientist may look in the flashlight's instruction manual for tips or conduct online search on how flashlights work using the manufacturer's or relevant websites. Scientist may even analyse information and past experiments or discoveries regarding the relationship between energy and light.

**Step 4: Formulate hypothesis**

With a question in mind, the researcher decides on what he/she wants to test (The question may have changed as a result of the literature review).
The research will clearly state what he/she wants to find out by carrying out the experiment. He/She will make an educated guess that could answer the question or explain the problem. This statement is called a hypothesis. A hypothesis guides the experiment and must be testable.

***Example:*** *Hypothesis*

- The batteries inside a flashlight give it energy to produce light when the flashlight is turned on.

**Step 5: Conduct experiment**

This step involves the design and conduct of experiment to test the hypothesis. Remember, a hypothesis is only an educated guess (a possible explanation), so it cannot be considered valid until an experiment verifies that it is valid.

***Example:*** *Experimental Procedure*

- Remove the batteries from the flashlight, and try to turn it on using the on/off switch.
  *Result: The flashlight does not produce light*
- Reinsert the batteries into the flashlight, and try to turn it on using the on/off switch.
  *Result: The flashlight does produce light.*
- Write down these results

In general, it is important to design an experiment to measure only one thing at a time. This way, the researcher knows that his/her results are directly related to the one thing he/she changed. If the experiment is not designed carefully, results may be confusing and will not tell the researcher anything about his/her hypothesis.

Researchers collect data while carrying out their experiments. Data are pieces of information collected before, during, or after an experiment. To collect data, researchers read the measuring instruments carefully. Researchers record their data in notebooks, journals, or on a computer.

### Step 6: Analyse data

Once the experiment is completed, the data is then analysed to determine the results. In addition, performing the experiment multiple times can be helpful in determining the credibility of the data.

***Example:*** *Analysis*

- Record the results of the experiment in a table.
- Review the results that have been written down.

### Step 7: Draw conclusions

If the hypothesis was testable and the experiment provided clear data, scientist can make a statement telling whether or not the hypothesis was correct. This statement is known as a conclusion. Conclusions must always be backed up by data. Therefore, scientists rely heavily on data so they can make an accurate conclusion.

If the data support the hypothesis, then the hypothesis is considered correct or valid.

If the data do not support the hypothesis, the hypothesis is considered incorrect or invalid. From here, if the hypothesis is invalid, the scientist can modify it and revert back to step 4.

***Example:*** *Invalid Hypothesis*

- The flashlight did NOT produce light when the batteries were inserted. Therefore, the hypothesis that batteries give the flashlight energy to produce light is invalid.

In this case, the hypothesis would have to be modified to say something like, “The batteries inside a flashlight give it energy to produce light when the batteries are in the correct order and when the flashlight is turned on.” Then, another experiment would be conducted to test the new hypothesis.
An invalid hypothesis is not a bad thing! Scientists learn something from both valid and invalid hypotheses. If a hypothesis is invalid, it must be rejected or modified. This gives scientists an opportunity to look at the initial observation in a new way. They may start over with a new hypothesis and conduct a new experiment. Doing so is simply the process of scientific inquiry and learning.

**Step 8: Communicate findings**

Scientists generally tell others what they have learned. Communication is a very important component of scientific progress and problem solving. It gives other people a chance to learn more and improve their own thinking and experiments. Many scientists' greatest breakthroughs would not have been possible without published communication or results from previous experimentation.

Every experiment yields new findings and conclusions. By documenting both the successes and failures of scientific inquiry in journals, speeches, or other documents, scientists are contributing information that will serve as a basis for future research and for solving problems relating to both the natural and physical worlds. Therefore, communication of investigative findings is an important step in future scientific discovery and in solving social, political, economic, cultural, and environmental problems.

***Example:*** *Communication of findings*

- Write your findings in a report or an article and share it with others, or present your findings to a group of people. Your work may guide someone else's research on creating alternative energy sources to generate light, additional uses for battery power, etc.

# Teaching and Learning Strategies

Scientific teaching emphasises and embraces the use of cognitive, reasoning, decision-making, problem solving and higher level thinking skills to teach to enhance students' understanding of inter-disciplinary concepts and issues in relation to environment, geography, history, politics and economic within PNG and globally. It aims to provide a meaningful pedagogical framework for teaching and learning essential and in demand knowledge, skills, values, and attitudes that are required for the preparation of students for careers, higher education and citizenship in the 21st Century.

Students must be prepared to gather and understand information, analyse issues critically, learn independently or collaboratively, organize and communicate information, draw and justify conclusions, create new knowledge, and act ethically.

These teaching and learning strategies will help teachers to;

- familiarize themselves with different methods of teaching in the classroom
- develop an understanding of the role of a teacher for application of various methods in the classroom

Successful teachers always keep in view that teaching must "be dynamic, challenging and in accordance with the learner's comprehension. He/she does not depend on any single method for making his/her teaching interesting, inspirational and effective".

A detailed table of Teaching and Learning Strategies are outlined below:

| STRATEGY | TEACHER | STUDENTS |
|---|---|---|
| CASE STUDY<br>Used to extend students' under-standing of real life issues | Provide students with case studies related to the topic of the lesson and allow them to analyse and evaluate. | Study the case study and identify the problem addressed. They analyse the problem and suggest solutions supported by conceptual justifications and make presenta-tions. This enriches the students' existing knowledge of the topic. |
| DEBATE<br>A method used to increase students' interest, involvement and participation | Provide the topic or question of debate on current issues affecting a bigger population, clearly outlining the expectations of the debate.<br>Explain the steps involved in debating and set a criteria/standard to be achieved. | Conduct researches to gather supporting evidence about the selected topic and summarising the points.<br>They are engaged in collaborative learning by delegating and sharing tasks to group members.<br>When debating, they improve their communication skills. |

# Strands, Units and Topics

The strand, units and topics are connected and aligned. The topics for each unit were derived from the grade level benchmarks. Unlike the units, the topics differ in grade levels. There are several topics for each unit depending on the content.

## Content overview

The teaching and learning of Science is organised under these four strands

- Science as Inquiry
- Life Science
- Physical Science
- Earth and Space Science.

Through achieving these strands, students' conceptual understandings of the biological, physical and earth and space world will be enhanced. The teaching and learning in these strands should be developed in conjunction with the Science as Inquiry strand. The emphasis placed on particular concepts may vary according to students' needs and location, including the physical, biological, technological and space nature of the environments in which they live.

**Grade 10**

| STRAND 1: SCIENCE AS INQUIRY | | |
|---|---|---|
| **Unit** | **Topic** | **Lesson Titles** |
| **Unit10.1 Scientific Tools and Technology** | **Lab Report** | What does a lab report look like? |
| | | Writing a good science reports |
| | **Scientific Calculator** | Understanding parts and functions of a scientific calculator |
| | | Application of functions of a scientific calculator |
| | **Telescope** | History and types of telescopes |
| | | Parts, functions and how to use a telescope |
| | | Making a simple telescope |
| | **Scientific Research Skills** | What is a scientific research skill? |
| | | Comparing scientific research with other types of research |
| | | Process of conducting a scientific research |
| **Unit10.2 Measurement and Accuracy** | **Scientific Notations** | Why is scientific notation important in science learning? |
| | | Learning how to apply scientific notation in science |
| | **Telling Time and Space in Relation to Natural Phenomena** | History of time and space |
| | | Why is time and space important in science and mathematics today? |
| | **Geological Maps** | Getting to know a geological map |
| | | Key components of a geological map |
| | | Designing a simple geological map using keys and components |
| | **Sources of Error** | Types and sources of error |
| | | Common types of error |
| | | Why is making error important to science learning? |
| | **Using Mathematical Functions in Science** | Mathematical functions needed in science |
| | | How to apply mathematical functions in science |
| | **Theories that can be proven as Mistaken or Fraudulent** | History of mistaken or fraudulent theories |
| | | Mistaken or fraudulent theories that have been proven |
| | | How do you prove that theories can be mistaken or fraudulent? |

| STRAND 2: : LIFE SCIENCE | | |
|---|---|---|
| Unit 10.3 Classifying Organisms | **Reproductive System** | Reproduction in plants |
| | | Reproduction in animals |
| | | Sexual reproduction |
| | | Male and female reproductive systems |
| | | Types of asexual reproduction in plants and animals |
| | | Diseases associated with human reproduction system |
| | | Similarities and differences in plants and animal reproduction |
| | **Inherited Traits** | Heredity and trait |
| | | Relationships between chromosomes, genes and trait |
| | | What is DNA? |
| | **Transferring Genetic Information** | Types of gene transfer |
| | | Methods of gene transfer in plants |
| | | Methods of gene transfer in animals |
| | | Use of genetic Information in plants and animals |
| Unit 10.4 Cell Structure and Function | **Tissues in Plants and Animals** | What are tissues? |
| | | Types of tissues in plants and animals |
| | | Parts and functions of tissues in plants and animals |
| | | Care for tissues in animals |
| | **Organs in Plants and Animals** | Multicellular and unicellular organisms |
| | | What are organs? |
| | | Types of tissues in plants and animals |
| | | Parts and functions of tissues in plants and animals |
| | | Comparing tissues in plants and animals |
| | | Care for tissues in plants and animals |
| | **Circulatory System** | Parts and functions of the Heart |
| | | Cells within the Heart and their functions |
| | | Organs of the Heart and their functions |
| | | Diseases associated with the Heart |
| | **The Musculoskeletal System** | The Human Skeletal System |
| | | Parts and Functions of human skeletal system |
| | | Comparing other skeletal systems |
| | | Other types of skeletal systems – exoskeleton systems |
| | | Diseases and risks associated with skeletal system |
| | | Parts and Functions of Muscular System - human |
| | | Parts and Functions of Muscular System – Other animals |
| | | Diseases and risks associated with our muscular system |
| | **Nervous System** | Nervous systems of the body |
| | | Nervous systems of the body |
| | | Parts and functions of the nervous system |
| | | Relationships between the nervous system, organs and tissues |
| | | Care and safety of our nervous system |
| | **Endocrine System** | What is endocrine system? |
| | | Types of endocrine systems in our body |
| | | Structures and functions of endocrine systems |
| | | Diseases of the endocrine systems |
| | | Health and care for endocrine systems |

| | | |
|---|---|---|
| Unit 10.5 Interactions and relationships in the environments | **Cycles in the Biosphere** | Types of cycles in the biosphere? |
| | | The water cycle |
| | | The carbon cycle |
| | | Importance of cycles in our life |
| | **Earth's Ecosystems** | What are the Earth's ecosystems? |
| | | Types and components of ecosystems |
| | | Structure and functions of types of ecosystems |
| | | Relationships between components of the ecosystem |
| | | Natural impact on ecosystems |
| | | Human impact on the ecosystem |
| | **Biodiversity and Succession** | What is biodiversity? |
| | | Successions within an ecosystem |
| | | Types of successions in an ecosystem |
| | | Examples of loss and degradation of natural habitats |
| **STRAND 3: PHYSICAL SCIENCE** | | |
| Unit 10.6 Matter and Energy | **Solubility** | Solubility |
| | | Types of Solutes and Solvents |
| | **Heat Transfer and Thermal Conductivity of Materials** | Energy and Chemical Change |
| | | Thermal Conductivity |
| | | Factors that Affect Thermal Conductivity |
| | **Systems and the Law of Conservation of Energy** | Conservation of Energy |
| | | Conservation of Matter |
| | **Chemical Reactions and Equations** | Combination Reaction |
| | | Decomposition Reaction |
| | | Single Displacement Reaction |
| | | Double Displacement Reaction |
| | | Combustion Reaction |
| | | Redox Reaction |
| | | Representing Chemical Reactions |
| | | Balancing chemical Reactions |
| | **Elements and Chemical Bonds** | The Nature of Chemistry |
| | | Non-polar Covalent Bonding |
| | | Polar Covalent Bonding |
| | | Hydrogen Bonding |
| | | Ionic Bonding |
| | **Work and Simple Machines** | Work |
| | | Energy |
| | | Power |
| | | Simple Machines-Lever |
| | | Simple Machines-Gears |
| | | Simple Machines-Incline Plane |
| | | Simple Machines-Pulleys |
| | | Mechanical Advantage |
| | | Velocity Ratio |
| | | Efficiency |

| | | |
|---|---|---|
| 10.7 Force and Motion | **Balance and Unbalance Forces** | Types of Forces |
| | | Weight |
| | | Friction |
| | | Balanced Forces |
| | | Unbalanced Forces |
| | | Vectors and Scalars |
| | | Adding Forces |
| | **Newton's Second and Third Laws of Motion** | Newton's Second Law of Motion |
| | | Net Force and Vector Sum |
| | | Application of Newton's Second Law |
| | | Newton's Third Law of Motion |
| | | Application of Newton's Third Law |
| | **Fluid Force** | Density |
| | | Specific Gravity |
| | | Pressure |
| | | Water Depth Pressure |
| | | Wind and Current |
| | | Heating and Chemical Effects |
| Unit 10.8 Waves, Electricity and Magnetism | **Mechanical Waves** | Transverse Waves |
| | | Longitudinal Waves |
| | | Properties of Mechanical Waves |
| | **Electromagnetic Waves** | Electromagnetic Spectrum |
| | | Radio Waves |
| | | Infra-red Waves |
| | | X-rays |
| | **Sound Waves** | Speed of Sound Waves |
| | | Properties of Sound Waves |
| | | Ultrasonic and Depth Finding |
| | | Loudness, Quality and Pitch |
| | **Properties of Light** | The Nature and Properties of Light Wave |
| | | Source of Light |
| | | Light and Optics |
| | **Electrical Current and Circuits** | Types of Electricity |
| | | Uses of Electricity |
| | | Household Electricity |
| | | Generating Electricity |
| | **Magnets and Electric Current** | Moving Charges |
| | | Magnetic Field |
| | | Electromagnetism |
| | | Magnets |
| | | Ampere's Law |
| | | Right Hand Grip Rule |

| STRAND 4: EARTH AND SPACE | | |
|---|---|---|
| Unit 10.9 Our Earth | **The Rock Cycle** | Types of rocks |
| | | The rock cycle |
| | **Minerals and Fossil Fuel** | Fossils – pre-history |
| | | What is fossil fuel? |
| | | Oil production in PNG |
| | | Minerals of PNG |
| | | Minerals and their properties |
| | **Natural Hazards** | Minerals and their properties |
| | | What are natural hazards? |
| | | Types of natural hazards |
| | | Sources of natural hazards |
| | | Causes and effects of natural hazards |
| | | Equipment used to measure and monitor natural hazards |
| | | Different types of natural hazards and safety involved |
| | **Causes and effects of Plate Tectonics** | Earth and plate tectonics |
| | | Causes of plate tectonics |
| | | Effects of plate tectonics |
| Unit 10.10 Weather and Climate | **Global Weather Systems** | Types of weather systems of the world |
| | | Regional weather system |
| | | Weather and ways of living |
| | | Ways of monitoring global weather patterns and systems |
| Unit 10.11 Space Science | **The Solar System and Beyond** | History of space discoveries |
| | | Formation of the solar system |
| | | Properties of planets, and other components of the solar system |
| | | What else is beyond our solar system? |
| | **Space Equipment, Usage and Functions** | What is space technology? |
| | | Spacecraft and instruments/equipment |
| | | How to use spacecraft equipment/instrument |
| | | Making a model of spacecraft |

# Grade 10 Science

## Teaching Content

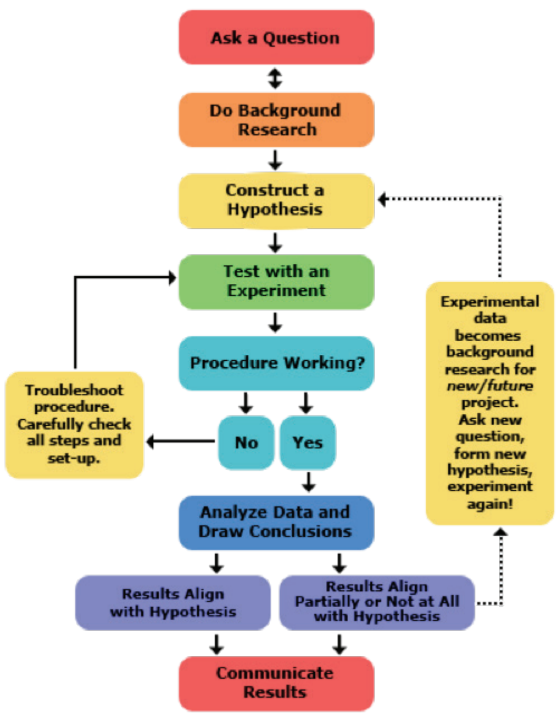
## Unit 10.1: Scientific Tools and Technology

Modern science and technology are interwoven into a complex that is sometimes called 'techno-science': the progress of science is dependent on the sophistication of instrumentation, whereas the progress of 'high-tech' instruments and apparatus is dependent on scientific research. Yet, how scientific research contributes to the development of instruments and apparatus for technological use, has not been systematically addressed in the philosophy of technology, nor in the philosophy of science. Philosophers of technology have taken an interest in the specific character of technological knowledge as distinct from scientific knowledge, thereby ignoring the contribution of scientific knowledge to technological developments. Philosophers of science such as the so-called New-Experimentalists, on the other hand, recently has become interested in the role of instrumentation, but merely focus on their role in testing scientific theories. By reviewing the two distinct developments and taking them a step further, an alternative explanation of the interwoveness of science and technology in scientific research is proposed. Additional to testing theories, instruments in scientific practice have an important role in producing reproducible phenomena, and these phenomena may have technological applications. Subsequently, technological development of these applications requires theoretical understanding of the phenomenon and of materials and physical conditions that produce it, is not for the sake of theories about the world, but for the sake of understanding a phenomenon and how it is technologically produced.

| Topic 1: Lab Report | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.4** Investigate a science-based societal issue by researching the literature, analysing data, and communicating the findings. |
| **Key question** | 1. Give some reasons why it is important to know and understand how to use lab reports in science?<br>2. Can you identify some ways of organising your lab reports when researching societal issues in order to communicate your findings scientifically? |
| **Learning objectives** | By the end of this topic, students can:<br>• Apply standard method of organising data and communicate findings in their research and investigations |
| **Vocabulary** | N/A |
| **Knowledge** | • Types of lab reports<br>• Process of organising data through lab reports |
| **Skills** | • Apply the skills of organising data in a scientific way<br>• Analyse relationships in between a set of data.<br>• Formulate conclusions and communicate findings in a scientific way. |
| **Attitudes and values** | • Accept the fact that in science, there are standard methods of organising findings, presenting and communicating results.<br>• Build self-esteem in terms of being a scientifically-minded student when solving science problems |
| **Teaching and Learning strategies** | • Demonstration of steps involved in writing lab reports<br>• Prepare steps using the content background on how to write a lab report for students to practice and get use to this. |
| **Assessment** | 1. Students demonstrate their understanding of how to write a lab report through a project using the rubric and samples lab report templates provided. |
| **Materials** | Handouts on different types of lab reports, blank lab report templates |

## Content Background

When conducting science investigations, there are standard methods that students can use and adapt to write the lab reports. Some of these methods are provided as examples for use by the students. However, in all lab report writing, the main processes used are those that are used in the science as inquiry approach shown on the right.




Lab reports are based on the science as inquiry process on the right but can be adjusted based on the type of report chosen.

When writing lab report, it is important to follow certain criteria. Presented below is a sample of a criteria or Lab Report Rubric that you can use to monitor students' performance during lab experiments.

## Lab Report Rubric

| Criteria | 4 | 3 | 2 | 1 |
|---|---|---|---|---|
| Title | Title is stated as a Question with correct punctuation and relates directly to topic | Title is stated as a Question with minor error punctuation and relates directly to topic | Title is stated as a Question with punctuation errors and indirectly relates to topic | Title is not stated as a Question and has several errors in punctuation or indirectly relates to topic |
| Materials | Materials list is complete and includes measurements so that experiments can be repeated. | Materials list is mostly complete and includes measurements so that the experiments can be repeated. | Materials list is incomplete includes limited measurements so that experiments can be repeated. | Materials list is incomplete and does not include limited measurements so that experiments can be repeated |
| Introduction | Well-written. Uses all proper science vocabulary to introduce topic | Well-written. Uses some proper science vocabulary to introduce topic. | Written in basic form. Uses minimal science vocabulary to introduce topic. | Written in basic form. Does not use science vocabulary to introduce topic. |
| Procedure | All procedures are written using complete sentences in order with detailed description of steps so the experiment could be repeated reliably. | All procedures are written using complete sentences in order with detailed description of steps so the experiment could be repeated reliably. | Only few procedures are written using complete sentences in order. Written with limited description of steps so the experiment would be difficult to repeat reliably. | Very few procedures are written using complete sentences in order. Written with very limited description of steps so the experiment would be impossible to repeat reliably. |
| Data | All data is presented in a manner that is organized and easy to read. Data includes graphs, charts, tables, measures, etc. | Most data is presented in a manner that is organized and easy to read. Data includes graphs, charts, tables, measures, etc. | Data is written but not well organized or incomplete. | Data is incomplete, unorganized and confusing to the reader. |
| Results | Statements of what was observed. Written in an easy to understand manner that ties observations to a conclusion. | State some of what was observed in a manner that ties observations to a conclusion. | States very little of what was observed in a manner that ties observations to a conclusion. | States only a little of what was observed but not in a manner that ties observations to a conclusion. |
| Analysis | Uses observations, data, vocabulary, and other evidence to create a well-supported statement showing knowledge gained. | Uses some evidence to create a statement showing knowledge gained. | Uses very few evidence to create a statement showing knowledge gained. | Uses no evidence and did not create a well-supported statement showing knowledge gained. |
| Conclusion | Detailed discussion of all aspects of experiment, results, suggestions, failures, etc and links to other relevant science knowledge. | Discussion of most aspects of experiment, results, suggestions, failures, etc and links to other relevant science knowledge. | Discussion of most aspects of experiment, results, suggestions, failures, etc but lacking links to other relevant science knowledge. | Discussion of some aspects of experiment, results, suggestions, failures, etc but lacking links to other relevant science knowledge. |
| Total Score | | | | |

Provided also below are two (2) samples of lab report templates that you can adjust and provide for your students to use during the lab experiments.

**Sample 1:**

| | |
|---|---|
| **School** ___________________ **Lab Report No** ____ <br> **Name** ___________________ **Class** ______________ **Date** ____________ | |
| **Problem, observation or Question… I wonder..** | What are you trying to find out about? Write this in the form of a question (only one(1) question.)<br>___________<br>___________<br>___________ |
| **Hypothesis … I think that…. Then…** | What do you think you are going to find out about?<br>___________<br>___________<br>___________ |
| **Materials** | List the materials you will use in the experiment<br>___________<br>___________<br>___________ |
| **Experiment Procedures** | Make a detail list of the steps in your experiment<br>___________<br>___________<br>___________ |
| **Data** | Record data collected in each step of the experiment<br>___________<br>___________<br>___________ |
| **Analysis… what I found out is….** | What did you observed when you performed the experiment?<br>___________<br>___________<br>___________ |
| **Conclusions… My hypothesis was…… because…..** | From what you observed, how would you answer your original question?<br>___________<br>___________<br>___________ |

**Sample 2**

**Lab Report No_____**

**Name:..............................................** **Class:.....................................** **Date:......../......./.......**

**Question** ***I wonder........................................................................................................................***

**Hypothesis** ***I think that if..................................................................................................................***
***then.............................................................................................................................................***

***Materials I need.........................................................................................................................***

**Procedures** ***Steps***
**.............................................................................................................................................................**
**Data collection** ***Results*****.............................................................................................................................**
**.............................................................................................................................................................**

**Results analysis** ***What I found out is*** ________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
__________
**Conclusion My hypothesis was .......................................................................................................**
**.............................................................................................................................................................**
**.............................................................................................................................................................**

**Tips to keep in mind when writing a Science Lab Report.**

*General*

- Must be typed, double-spaced, standard margins, standard white paper.
- No collaboration with anyone. This means that you may discuss your lab report with others, but you are to ensure that no part of the lab report is plagiarized from anyone else.

*Specific*

- No plagiarism from an outside source. Information taken from an outside source (any source other than your brain) must be paraphrased and cited. DO NOT copy word for word from any source.
- Make sure you are clear and concise. A Lab Report is not the place for flowery prose (just decorations). However, all information must be presented in paragraph form, not outline or bulleted form.
- Throughout your report, write/use proper scientific language.
- Use the correct abbreviations
- Learn how to add superscripts/subscripts, appropriate symbols and Greek characters (i.e., m) on the computer.
- It is proper to use digits in scientific papers instead of spelling out numbers.
- Write numbers with correct spacing and format: 3 ml NOT 3mL or three ml or 3 millimetres.
- All parts of the report should be in 3rd person, past tense, passive voice.

*For example:*

- The goldfish were placed into $21^0$C water
- NOT: I placed the goldfish into $21^0$C water.
- You should not have any “I,” “you,” “we,” or “our” in your paper.
- Always have a Title Page for all your Lab Reports.

| Topic 2: Scientific Calculator | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.1** Manipulate and improvise tools and technology to perform tests, collect data, analyse relationships, and display data. |
| **Key question** | How do I solve scientific problems that involve calculations? |
| **Learning objectives** | At the end of this topic, students can:<br>• Apply different skills and techniques in using a scientific calculator to solve scientific, engineering and mathematical problems. |
| **Vocabulary** | • Parenthesis, exponents, fractions, mathematical constant *e*, logarithms, recall functions, scientific notation, |
| **Knowledge** | • Parts and functions of a scientific calculator<br>• Basic steps involved in understanding the use of a scientific calculator |
| **Skills** | • Apply functions of a scientific calculator in science and mathematics lessons |
| **Attitudes and values** | • Value the importance of understanding the parts and functions of a scientific calculator in different contexts |
| **Teaching and Learning strategies** | • Teacher to make calculators available for students to use in order to learn and under-stand the basic steps involved in using a scientific calculator |
| **Assessment** | 1. Students demonstrate their understanding of how to use a scientific calculator |
| **Materials** | Picture of calculator and parts and functions, scientific calculators, handouts on the basic steps in using a scientific calculator |

## Content Background

A scientific calculator is a type of electronic calculator, usually but not always handheld, designed to calculate problems in science, engineering, and mathematics. They have completely replaced slide rules in traditional applications, and are widely used in both education and professional settings.

There are many different types of calculators out there and are used for many different purposes. However, the type of calculator selected should be based on the complexity of the problems (scientific, engineering and mathematical) that are prescribed in the school curriculum. Therefore, teachers are required to help students learn the basics of how to use the type of calculator selected.

Using a calculator can be extremely helpful but not only if you know its particular conventions. While there are different types out there, many of their features are the same. This information provided will help you have your calculator at hand as you follow along.

**Getting to Know Your Calculator**

- Look for the number pad and the four basic operations, multiplication **(X)** addition (**+)** subtraction **(–)** and division (**÷)**.
- To perform a calculation, make the necessary keystrokes and then hit ENTER. For example, key 4 ÷ 2 ENTER. The calculator should show the answer we expect which is 2.
- Try some small calculations, like 2 ÷ 3 and 4 x 5, and take note of the following:
  - Is the input still showing on the screen after I hit ENTER?
  - Can I scroll back through previous inputs using *arrow* keys?
  - The answers to these questions will depend on what type of calculator you have.

## Calculator tips

- Check out your syllabus content to find out what types of calculators are recommended or allowed for your particular course, units or topics, and when they can be used. If you are not sure, ask the HOD.
- All calculations, whether it be classroom tasks, tests (approved), or homework, the same calculator must be used.
- Always make sure that extra batteries are made available for calculators that use batteries. Students can be asked to buy their own batteries as well.
- Discourage the use of other types of calculators, mobile phones or computers in order to maintain consistency in the processes and results.

Teachers are encouraged to modify or expand these tips based on the subject content/complexity and the understanding level of students.

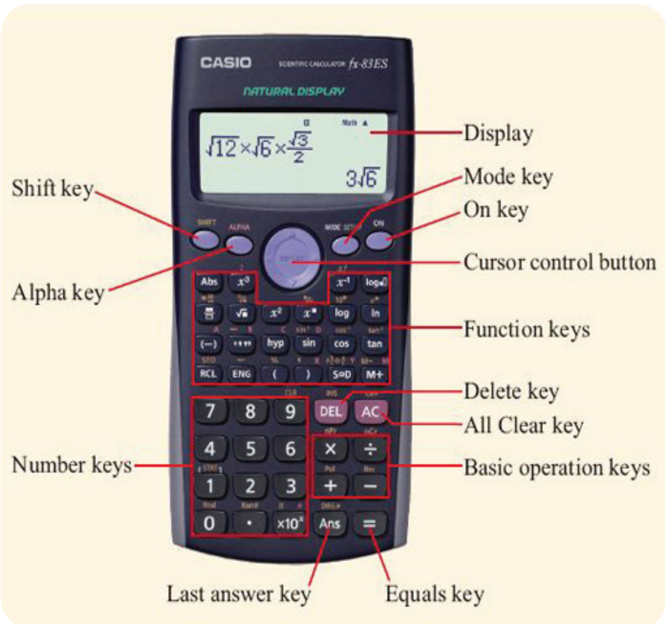
### The Order of Operations

If your calculator is a scientific calculator, it follows the order of operations, which students may have learned in their maths classes. It goes like this:

- Parenthesis
- Exponents
- Multiplication/Division
- Addition/Subtraction.

- Beware that this means that multiplication and division should be performed from left to right in the expression regardless of their order, and the same with addition and subtraction.
- If your calculator is NOT a scientific calculator, it does NOT follow order of operations and calculates the result in the order in which the entries were made. In this case, you will not get a correct answer so you will have to adjust how you will enter the values. To see if your calculator has algebraic logic, enter 2 + 3 x 4.
  - If you get 14, it has algebraic logic.
  - If you get 20, it does not.

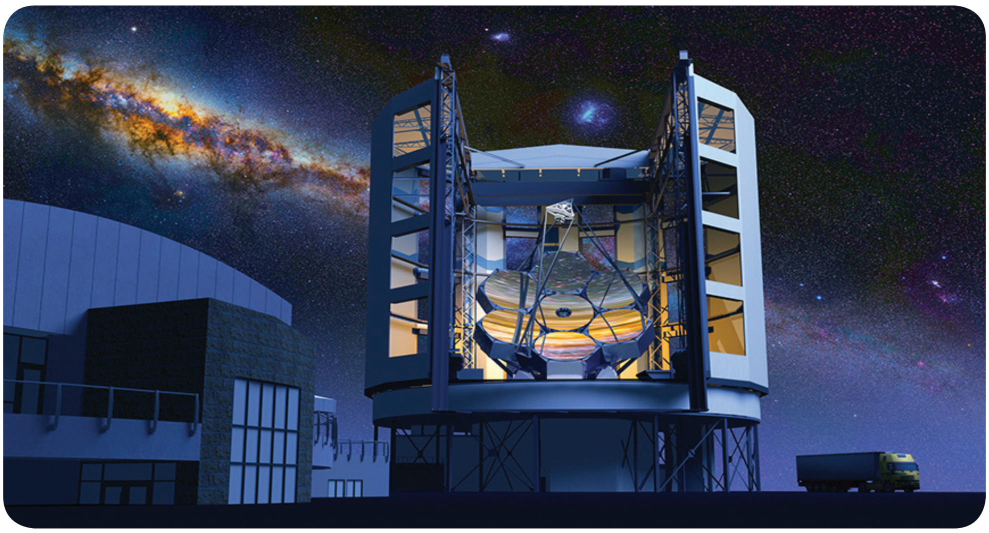
An example of a Super Scientific Calculator and explanations of applications of some of the functions is given below.



| Topic 3: Telescope | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.1** Manipulate and improvise tools and technology to perform tests, collect data, analyse relationships, and display data. |
| **Key question** | Why is it important to learn and know about telescopes and how they are used? |
| **Learning objectives** | At the end of this topic, students can:<br>• Apply the basic principles involved in designing and using a telescope<br>• Design and demonstrate how to use a simple telescope |
| **Vocabulary** | Refracting telescope, reflecting telescope, Hubble space telescope, ground-based telescope, space-based telescope |
| **Knowledge** | • Different types of telescopes<br>• Parts and functions of a simple telescope<br>• Importance of telescope in astronomy |
| **Skills** | • Make models<br>• Evaluate the use and importance of telescopes<br>• Apply the skills in the design and usage of a telescope |
| **Attitudes and values** | • Appreciate the work done by famous scientists in the discovery and use of telescopes and their purpose in the study of universe. |
| **Teaching and Learning strategies** | • Teacher to prepare and trial out a model of a simple hand-held telescope and use this as sample for students to see in order to make their own models of telescopes. |
| **Assessment** | 1. Design a simple hand-held telescope using available resources such as convex and concave mirrors, hard paper tubes or similar (STEAM project) |
| **Materials** | Pictures of different types of telescopes. Paper tubes, concave and convex mirrors |

## Content Background

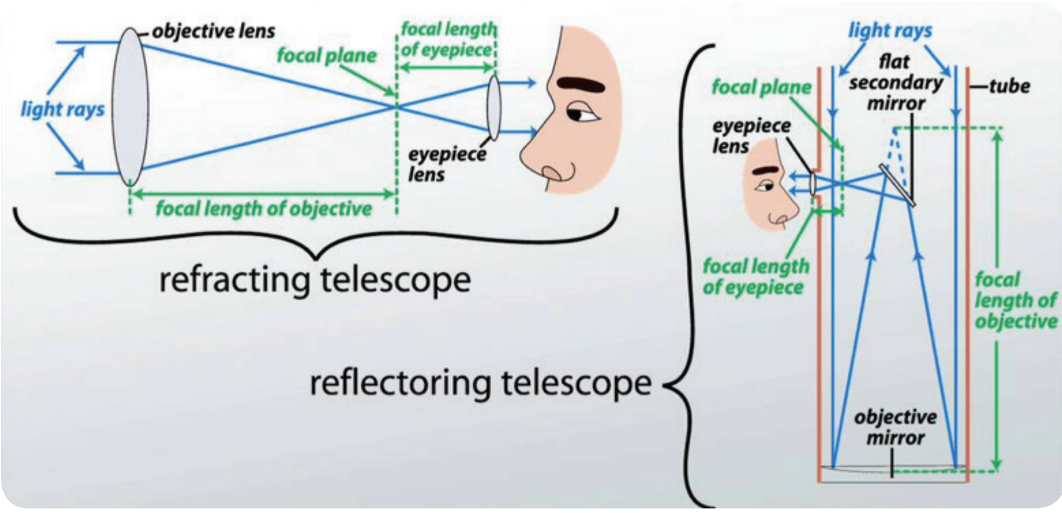
How did the universe begin? Are there any other objects like Earth out there? Are we alone or are there other intelligent beings somewhere out there? These are some types of questions that keep astronomers busy. They search the skies for clues that will one day lead to answers. With modern technology, scientists hope to create new tools to help them find answers with the aid of modified high level telescopes such as the 'Giant Magellan Telescope (GMT)' show below.



Described in the diagrams below are two types of telescopes.

1. The Refracting Telescope, and
2. The Reflecting Telescope

**Types of telescopes**

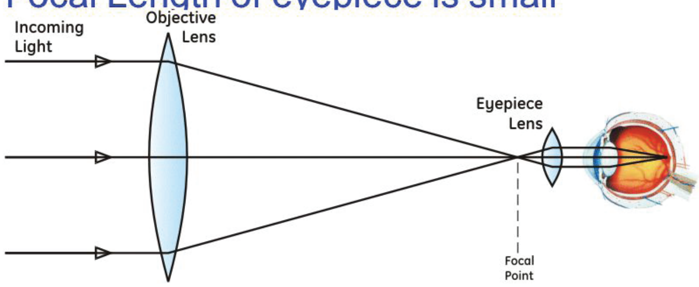



## 1. Basic Telescope Design

**a. <u>Refractor Telescope</u>** (objective is a lens)

Focal Length of Objective is big

Focal Length of eyepiece is small




We see the evolution of a miniscule, optical telescope, ultimately leading to the far more advanced Hubble Space Telescope. The actual inventor of the telescope will never be known; however, Hans Lippershey is generally credited as being the inventor of this instrument that would soon transform our world. Beginning with the birth of the telescope, Goldsmith engages us in a cosmic journey that would ultimately allow us to study our ever expanding universe in all parts of the electromagnetic spectrum on Earth and in space. Originating in Europe, the telescope first became revolutionized by Galileo, who used a spyglass to discover many cosmic objects in outer space, such as Jupiter having four moons.

We've learned a little of the history of the telescope, and how it was revolutionized by Galileo. Additionally, we've learned the difference between refracting and reflecting telescopes (see diagrams shown). Refracting telescopes use lenses, whereas, reflecting telescopes use mirrors to collect lights. Through astronomical methods, such as the Doppler Effect, planets, otherwise known as exoplanets, were discovered. Because of the turbulence in our atmosphere, ground- based telescopes have their angular resolution limited. However, through space-based telescopes, such as the Hubble Space Telescope, fascinating images of our universe have been captured by NASA and can be seen in many publications today.

Originally, the Earth was thought to be the center of our solar system through the geocentric theory, which was discovered by Ptolemy. However, then came the Copernican revolution, and with it the Heliocentric theory

The sun is the center of the solar system -, which would be proven by Galileo. It was Galileo that discovered lunar craters, the disk and four main moons of Jupiter, countless stars in the Milky Way, the phases of Venus and sunspots. As centuries pass by, the telescope that originally began with the spyglass has now been revolutionized into much larger, reflecting telescopes. Although not the first space telescope, Hubble is one of the largest and most versatile, and is well known as both a vital research tool and a public relations boon for astronomy.

| Topic 4: Scientific Research Skills | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.1** Manipulate and improvise tools and technology to perform tests, collect data, analyse relationships, and display data. |
| **Key question** | What are the basic scientific research skills that are needed to write up a good science report? |
| **Learning objectives** | At the end of this topic, students can:<br>• Apply the basic scientific research skills needed to write a good science report |
| **Vocabulary** | Quantitative research, qualitative research, |
| **Knowledge** | • Processes involved in carrying out a scientific research |
| **Skills** | • Apply scientific research skills<br>• Critical thinking skills<br>• Problem solving skills<br>• Analysing and communicating skills |
| **Attitudes and values** | • Promote independence, objectivity and unbiased attitude when carrying out a research. |
| **Teaching and Learning strategies** | • Teacher to prepare notes on how to carry out a scientific research for students.<br>• Identify topics that students will be engaged in when carrying out scientific research. |
| **Assessment** | 1. Identify and apply scientific research skills through a project or in science experiments |
| **Materials** | Handouts on how to carry out a good science research, topics for scientific research. |

## Content Background

### Research

This method says that design, execution and evaluation are interlinked and not independent of each other. The foundation consists of departure points, the topic, the objectives and the methods. Researchers have three important characteristics:

1. Attitude: a good researcher should be objective; personal preferences should play NO role in your research. You must also be open, by this; it means that you will not ignore findings that might contradict your previous or hypothesis.
2. Knowledge
3. Skills

Doing research starts with a research plan where you define the problem. Also you decide whether your research is fundamental of practical or qualitative or quantitative. To define the quality of a scientific research, there are certain rules or objectives the research must follow.

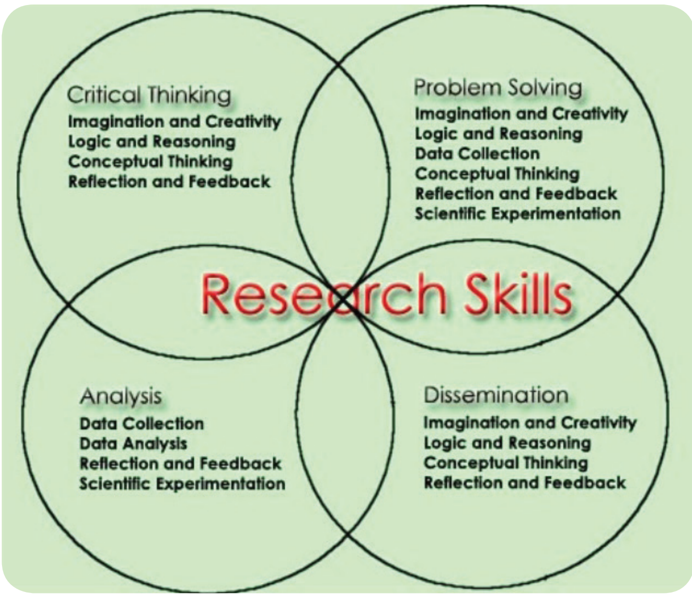
- **Independence:** unbiased and objectivity. Inter-subjectivity is when researchers agree with one another as far as the results are concerned.

There are two distinct types of research:

**1. Quantitative research:** Quantitative research is based on numerical information and figures that represent object, organisations and people. Tools used for quantitative research are statistics.

2. **Qualitative research:** Qualitative research is practiced in the field. It is mainly interested in the meaning that a person attaches to a situation or experience. The research subjects are studied in their environment as a whole known as holism. Methods used for this research are open and flexible where you can interpret unexpected happenings. The most important aspect is the value and meaning that people attach to situations and issues.

The basic scientific research skills are outlined in the diagram below. Teachers are encouraged to ensure that these skills are applied at all times when students are engaged in science research. These skills can also be adjusted and applied when students are carrying out science experiments during normal classroom science lessons.




**Make reference to science as inquiry approach in the syllabus and this teacher guide for more information.**

### Characteristics of research

The following are the main characteristics of a scientific research.

- **Purpose:** The purpose of research is clearly stated.
- **Solution:** It is oriented and directed towards the solution of a problem.
- **Relation:** Determines the relation between two or more problems.
- **Skills:** Research requires a careful skill in recording and reporting data.
- **Knowledge:** Research requires that the researcher must have full knowledge of the problem that is at hand.
- **Replication:** research is replicable. The design, procedures and results of scientific research should be replicable so that any person other than the researcher assess the validity of research or can reproduce the study.

### Guidelines for writing a successful research paper

The guidelines given in the mind map below can be used by teachers to guide students to write good research papers using the scientific way of carrying out a research or use in normal science lessons. Teachers are encouraged to make adjustments to these guidelines based on your students' need and level or grade.


Guidelines for Writing a Successful Research Paper
Use a unique style of writing
Have a clear understanding of the contents.
The writing should be simple; avoid unnecessary jargons
Develop in-depth knowledge of the subject
Use innovative ideas and ways to justify the research work
Explain different scientific terminologies and provide a track of bibliography
To strictly follow all the specifications of the approving & publishing authority
Thoroughly proofread from top to bottom of the research paper

## Unit 10.2: Measurements and Accuracy

Accuracy of a measured value refers to how close a measurement is to the correct value. The uncertainty in a measurement is an estimate of the amount by which the measurement result may differ from this value. Precision of measured values refers to how close the agreement is between repeated measurements.

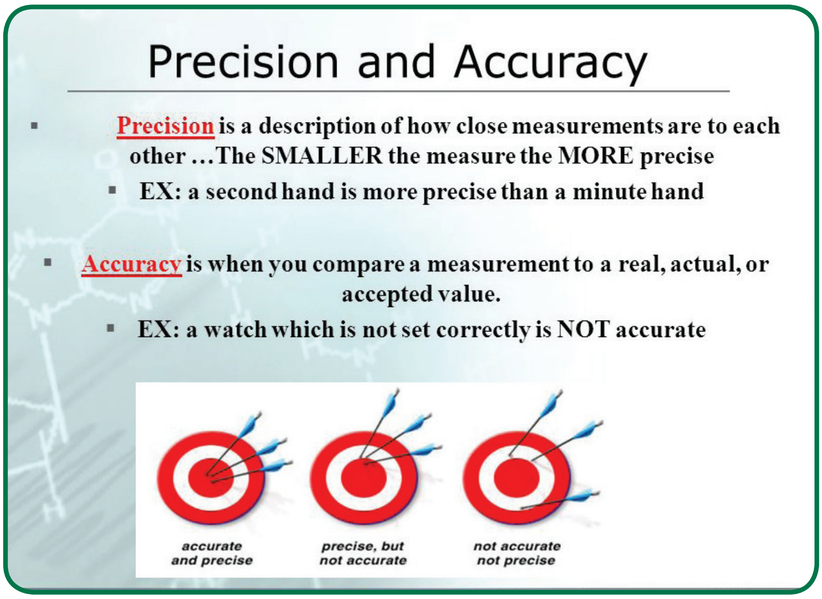
**Precision and Accuracy Errors in Scientific Measurements**

- **Precision** – Refers to reproducibility or "How close the measurements are to each other."
- **Accuracy** – Refers to how close a measurement is to the real or true value.
- **Systematic Error** – Produces values that are either all higher or all lower than the actual value
- **Random Error** – In the absence of Systematic Error, produces some values that are higher and some that are lower than the actual value.

How do you measure the accuracy of an instrument?
The **accurate** measurements are near the center. To **determine** if a value is **accurate** compare it to the accepted value. As these values can be anything a concept called percent error has been developed. Find the difference (subtract) between the accepted value and the experimental value, then divide by the accepted value.

In measurement of a set, accuracy refers to closeness of the measurements to a specific value, while precision refers to the closeness of the measurements.

**How to Calculate the Accuracy of Measurements**




To determine the **accuracy** of a **measurement**, calculate the standard deviation and compare the value to the true, known value whenever possible.

| Topic 1: Scientific Notations | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.3** Analyse situations and solve problems that require combining and applying concepts from more than one area of science. |
| **Key question** | Why do we need to study the basics of scientific notations in science? |
| **Learning objectives** | At the end of this topic, students can:<br>• Apply significant figures and scientific notations in scientific problem –solving situations. |
| **Vocabulary** | • Significant figures, systematic error, random error, accuracy, precision, scientific notation |
| **Knowledge** | • Significant figures and ways of understanding these<br>• Scientific notations and how these are applied in science lessons |
| **Skills** | • Critical thinking<br>• Problem-solving |
| **Attitudes and values** | • Appreciate the importance of mathematical functions such as significant figures and their applications in science lessons. |
| **Teaching and Learning strategies** | • Teacher should consult mathematics teachers to assist in providing guidelines and advice on how to perform calculations using significant figures and scientific notations. Handouts on the processes together with what is provided in the background below will be very handy. |
| **Assessment** | 1. Solve scientific problems using significant figures and scientific notations. |
| **Materials** | Handouts on rules and processes involved in calculations using significant figures and scientific notations, scientific calculators, worksheets. |

## Content Background

**Accuracy versus Precision**

In labs, we are concerned by how "correct" our measurements are, they can be accurate and precise

Accurate: How close a measured value is to the actual measurement
Precise: How close a series of measurements are to each other.

For example:
The true value of a measurement is 23.255 mL. Below are 2 sets of data. Which one is precise and which is accurate?
1. 23.300, 23.275, 23.235 (Precise)
2. 22.986, 22.987, 22.987 (Accurate)

We want our measurements to be as precise and accurate as possible. For precision, we make sure we calibrate equipment and take careful measurements. For accuracy, we need a way to determine how close our instrument can get to the actual value

**SIGNFICANT FIGURES**

We need significant figures to tell us how accurate our measurements are. The more accurate the number is- the closer it is to the actual value.

Look at this data. Which is more accurate? Why? 25 cm, 25.2 cm, 25.22 cm
ANSWER: 25.22cm - The more numbers past the decimal (the more significant figures ), the closer you get to the true value.

**How do we determine how many significant figures are in different pieces of lab equipment?**

Significant Figure: Any digit in a measurement that is known for sure plus one final digit, which is an estimate. Example: 4.12 cm. This number has 3 significant figures. The 4 and 1 are known for certain. The 2 is an estimate. In general, the more significant figures you have, the more accurate the measurement will be. For determining significant figures with instrumentation, find the mark for the known measurements, and then estimate the last number between marks.

SIGNIFICANT FIGURES › Try these: › Graduated cylinder Triple Beam balance › Ruler

Rules for significant figures

Rule 1: Nonzero digits are always significant
Rule 2: Zeros between nonzero digits are significant. For example: 40.7 (3 sig figs.), 87009 (5 sig figs.)
Rule 3: Zeros in front of nonzero digits are not significant. For example: 0.009587 (4 sig figs.). 0.0009 (1 sig figs.)
Rule 4: Zeros at the end of a number and to the right of the decimal point are significant. For example: 85.00 (4 sig figs.). 9.070000000 (10 sig figs.)
Rule 5: Zeros at the end of a number are not significant if there is no decimal. For example: 40,000,000 (1 sig fig)
Rule 6: When looking at numbers in scientific notation, only look at the number part (not the exponent part). For example: 3.33 x 10 -5 (3 sig fig). 4 x 10 8 (1 sig fig)
Rule 7: When converting from one unit to the next keep the same number of sig. figs. For example: 3.5 km (2 sig figs.) = 3.5 x 10 3 m (2 sig figs.)

How many significant figures are there in the sample numbers below?

1. 35.02
2. 0.0900
3. 20.00
4. 3.02 X 10 4
5. 4000

Answers: (1) 4 (2) 3 (3) 4 (4) 3 (5) 1

**Rounding to the correct number of sig figs.**
Many times, you need to put a number into the correct number of sig figs. This means you will have to round the number. EXAMPLE: You start with 998,567,000. Give this number in 3 sig figs. ANSWERS:

**Step 1:** Get the first 3 numbers (3 sig figs.) 998
**Step 2:** Check to see if you have to round up or keep the number the same. You need to look at the 4 th number. For instance, given the number 998 5. If the next number is 5 or higher, round up. If the next number is 4 or less, it stays the same. So it rounded to 999.
**Step 3:** Take your numbers and put the decimal after the first digit. It is 9.99
**Step 4:** Count the number of places you have to move to get to the end of the number and put it in scientific notation. So it becomes 9.99 x 108 (NOTE: If the number is BIG it will be a positive exponent. If the number is a DECIMAL, it will be a negative exponent.)

| Topic 2: Telling Time and Space in Relation to Natural Phenomena | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.2** Examine the cumulative nature of scientific evidence. |
| **Key question** | What are the relationships between time and space in relation with natural phenomenon? |
| **Learning objectives** | At the end of this topic, students can:<br>• Apply comparative thinking and form an opinion that understanding the relationships between space and time as human nature is still an illusion and will take million more years for humankind to fully solve this mystery. |
| **Vocabulary** | Quantum mechanics, natural phenomena, space-time continuum |
| **Knowledge** | |
| **Skills** | Construct, reconstruct and deconstruct personal views and understanding of time and space in relation to natural phenomena.<br>Analyse and deduce meanings of current scientific evidence in relation to time and space as presented. |
| **Attitudes and values** | Promote openness and independence when expressing views about time and space as expressed in scientific discoveries. |
| **Teaching and Learning strategies** | Teacher will need to do more research into the nature of space and time in relation to natural phenomena. Students should be encouraged to do research in the library or through internet. Maybe log on to/link or find books on:<br>*Rowe, E.G.Peter (2013). Geometrical Physics in Minkowski Spacetime (illustrated ed.). Springer Science & Business Media. p. 28. ISBN 978-1-4471-3893-8. Extract of page 28*<br>*^ Rynasiewicz, Robert. "Newton's Views on Space, Time, and Motion". Stanford Encyclopedia of Philosophy. Metaphysics Research Lab, Stanford University. Retrieved 24 March 2017.* |
| **Assessment** | 1. Research and present views and opinions (no right/wrong answer) on concepts of space and time in relation to natural phenomena. |
| **Materials** | Wikipedia, library, handouts, internet, video. |

## Content Background

This topic is quite abstract, which means most of the learning will be done as theory lessons. Students should be engaged in discussions about understanding the concepts of time and space in relation to the simplest meanings of these concepts as well as natural phenomena which includes space discoveries and literature.

- What is meant by time and space?

**Space** is a form of coordination of coexisting objects and states of matter. ... It consists in the fact that objects are extraposed to one another (alongside, beside, beneath, above, within, behind, in front, etc.) and have certain quantitative relationships.

- Who introduced the concept of time?

The measurement of time began with the invention of sundials in ancient Egypt some time prior to 1500 B.C. However, the time the **Egyptians** measured was not the same as the time today's clocks measure. For the **Egyptians**, and indeed for a further three millennia, the basic unit of time was the period of daylight.

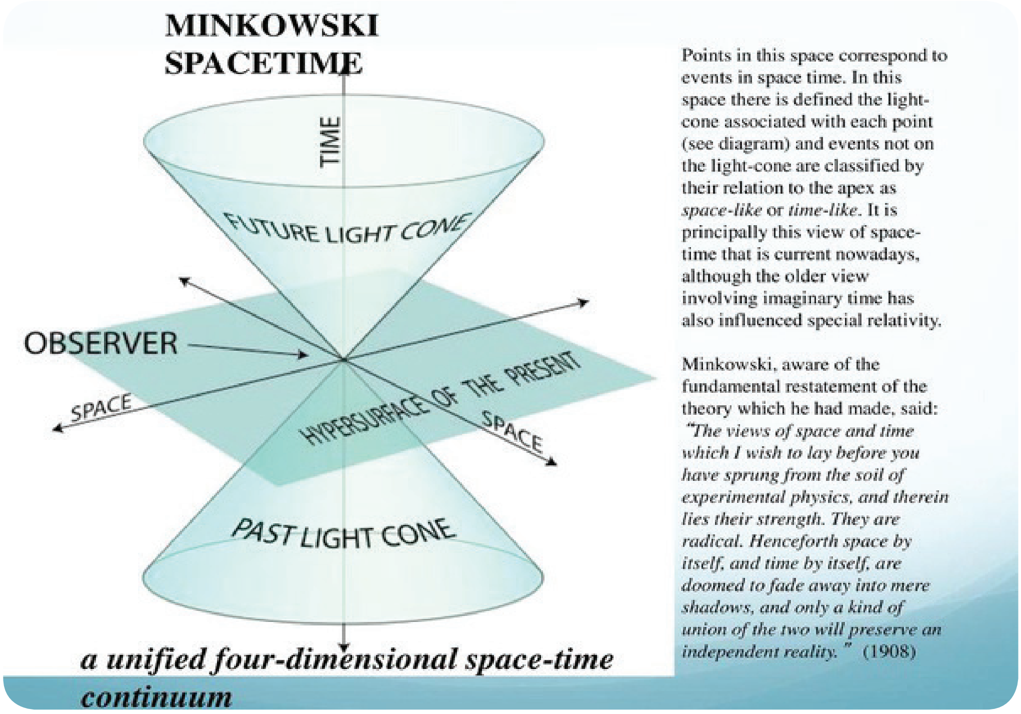
Einstein's theory of **special relativity** says that time slows down or speeds up depending on how fast you move relative to something else. Approaching the speed of light, a person inside a spaceship would age much slower than his twin at home. Also, under Einstein's theory of **general relativity**, gravity can bend time.

What is Einstein's concept of time?

While most people think of **time** as a constant, physicist Albert **Einstein** showed that **time** is an illusion; it is relative — it can vary for different observers depending on your speed through space. ... The bending of space-**time** causes objects to move on a curved path and that curvature of space is what we know as gravity.

- How does space time work?

**Space-time** is a mathematical model that joins **space** and **time** into a single idea called a continuum. This four-dimensional continuum is known as Minkowski **space**. ... Also, the strength of any gravitational field slows the passage of **time** for an object as seen by an observer outside the field. (see illustrations below)




- What is the principle of space and time?

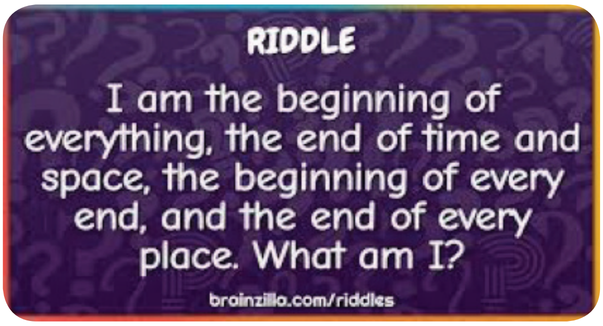
**Space**-**time**, in physical science, single concept that recognizes the union of **space and time**, first proposed by the mathematician Hermann Minkowski in 1908 as a way to reformulate Albert Einstein's special theory of relativity (1905). Common intuition previously supposed no connection between **space and time**.

- Is space and time the same thing?

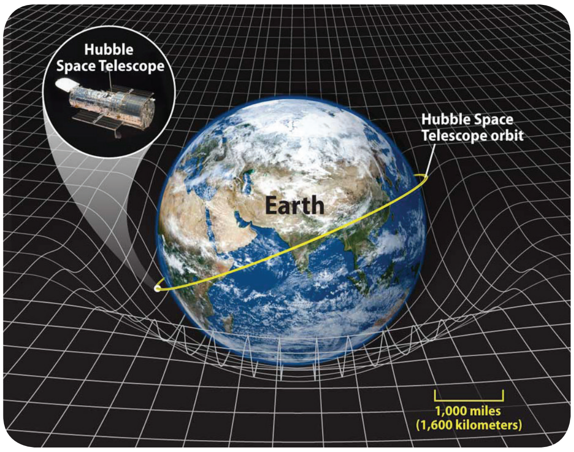
**Space and time** are not the **same thing**, but they are both parts of one **thing**, called spacetime . They are regarded as parts of one **thing** because, in light of relativity theory, measurements of **time** and distance alter in relation to one another and in relation to velocity.

**Conclusion – discussion points**

A. Get the students to discuss and find possible answers to the riddle given below (no answer is correct because biblical minded students will also give God as the answer)




B. Get students to research and find out about:
- The Hubble Space Telescope
- The purpose for sending it out there
- How far is it from the Earth, and
- How long will be out there in space



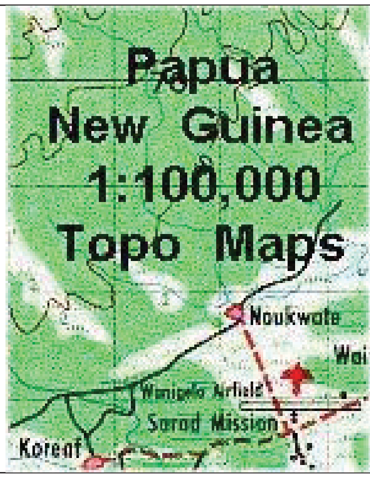
## Topic 3: Geological Maps

| | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.5** Read and interpret topographic and geologic maps. |
| **Key question** | What basic skills do you need to know in order to understand how to read and design geological maps? |
| **Learning objectives** | At the end of this topic, students can:<br>• Apply reading and designing skills in their understanding of geological maps.<br>• Explain processes, including scaling involved in the development of geological maps |
| **Vocabulary** | Geographical Positioning System (GPS), topographical maps, strike, dip, gridding, topographic contour lines |
| **Knowledge** | • General principles of geological mapping.<br>• Difference between traverse, outcrop, structural and geographical maps.<br>• Understanding the format of a geological survey map.<br>• Understanding the scales and coordinates of a geological map. |
| **Skills** | • Construct samples of geological maps using basic skills of designing geological maps.<br>• Interpret data given in geological maps.<br>• Make model designs of geological maps. |
| **Attitudes and values** | • Show care and concern of the causes and effects to life and landscape if poor geological maps are designed. |
| **Teaching and Learning strategies** | Teacher may need the assistance of an expert (geologist, engineer) in this topic. Invite experts if needed and provide guiding questions for the expert based on the content and student's needs. Some research is needed for teacher background information. |
| **Assessment** | 1. Design a geological map using guidelines given with structures and labels correctly done. |
| **Materials** | Samples of geological maps (PNG) and other countries, mapping grids, compass, ruler, geological terms (defined). |

## Content Background

**General principles of geological mapping**

- Preparing to go to the field
- Things needed
- Uses of G.P.S (geographical positioning system)
- Gridding of topographical map
- Difference between traverse, outcrop, structural and geographical maps



**Reading and understanding geological maps**

After going through this topic with your students, they should be able to;

- Understand the format of a geological survey map
- Be familiar with the presentation of data on such maps
- Recognise simple geological features from a map
- Be able to sketch a cross-section through a map
- Be able to present a summary sketch map

**What do geological survey maps show?**
Geological data is 3-dimensional; as exploration geophysicists you are interested in the arrangement of rock below the ground. Although seismic, magnetic, and gravity data, among other techniques, will tell you much of what you need to know, all clues help.

**Terminology**

Before we go any further, we need to define some simple geological terms. Think about **sedimentary rocks** (those that form in orderly layers). If the layers of rock are **planar** (horizontal), with constant thickness and continue forever, then these are said to have **layer-cake stratigraphy** (this is rare in practice, but useful for now to help visualize these ideas). We deal with structures in terms of orientation of the planes (the boundaries between **units** or **beds**). Bed is an informal term referring to individual, often relatively thin layers within the rock. Loosely, each bed over a short period of time; often, the surface of a bed formed the sediment surface at some point in the past. Units are collection of adjoining beds that are grouped together when they have some similarity, e.g. mineralogy, paleontology or particular structures that indicate a common process in their origin. Units are grouped together in stratigraphy as formations and members of formations.

**What do the outcrop patterns of these beds tell us?**

Outcrop patterns represent the intersection of the 3-dimensional shape of the rock with the land surface. Where the rocks are flat and the land is not, then boundaries will outcrop along topographic contour lines.

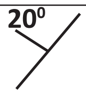
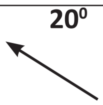
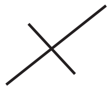
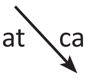
**Understanding the scale and coordinates of a geological map**

Maps in general come in a variety of scales depending on the amount of detail needed for different purposes. In all cases, they will show a grid for location (in Britain, the National Grid on land), almost always with North at the top. Points on the map are referred to using coordinates (eastings then northings) which are usually 6 or 8 figure references. The basic grid square covers 100, 000 metres, with northings, for example, given as $^{0}70^{00}$ mN, giving an absolute location in metres. When working within a map, it is usual to give 3 figures (e.g. 700N) or 4 figures (e.g. 7000), depending on the scale of the map. Four figure grid references specify locations to within 10 metres. Maps covering a larger area tend to use latitude and longitude in addition or instead. Maps for other countries will use other National Grids.

**What is strike and dip?**

Geologists define the orientation of dipping beds using the terms **strike** and **dip**.
**Strike** is the azimuth (bearing on a compass) of ta horizontal line on a bed i.e a line perpendicular to the steepest angle of dip). This is always given as a *3 figure number*, e.g. 090 for a bed striking East-West.

Dip is the angle from the horizontal of the steepest gradient of the bedding surface. This is *2 figure number* (e.g. a horizontal bed has a dip of 00⁰). It has an orientation and dip arrows always pointing down dip. The two combined as given as 256/45 SE, for example, fully defining the orientation of a plane. Strike and dip are generally marked on maps, using a combination of symbols and figures, these are given in the table below.

| Symbol | Description |
|---|---|
|   | Strike and dip of bedding 043/20 NW |
|   | Strike and dip of bedding 043/20 NW |
|  | Strike and dip of vertical bedding |
|  | Strike and dip of horizontal bedding |
| Please note that  can also refer to a linear feature | |

Strike and dip measured with a **compass/clinometer**, on an area about 10 cm x 10 cm.

**Synthesis of geological maps**
The data presented on even simple geological maps can be very confusing. We need to simplify it, in order to answer whatever questions we have about the area. There are two ways to do this, which may be appropriate in different cases:

- Cross section (precise or sketch)
- Sketch map

Begin by dividing the map up into geologically sensible regimes (use faults and unconformities to define domains on the map). Put these boundaries onto your sketch map (as well as grid scales and refs). Then, look at the map and deduce the orientation of the rocks in each area: which way do they dip? Are they steep or shallow? Are there folds? Are there important faults? Etc.. Use a key to and colour or shade your map to show important groups of rocks. Show the dip direction and amount for each domain.

**Hints and tips for sketch/summary maps**

*A good sketch map:*

- Is the same shape as the original map.
- Is easy to relate to the original map, i.e. it uses similar colours and ornament, if needed, and has grid lines, key and scale shown clearly.
- Is a sketch, i.e. it reproduces the general form of key boundaries without following every twist and turn on the map
- Reproduces accurately, but not in full detail, significant outcrop shapes, boundaries and cross-cutting relationships.
- Give indications of topography, for example showing spot heights on high ground and major rivers to show valleys.

- Summarises complex stratigraphy, for example by grouping units with similar histories together and treating them as one unit.
- Highlights important features such as major faults and folds by marking them and showing as much information deduced from the map overall as possible. For example, folds can be shown as axial traces, synformal or antiformal, with younging directions marked. Faults traces should show dip direction, downthrow side and throw (if known) marked according to convention.
- Is annotated, to indicate complexities not easily summarised, e.g. “region of many parallel steep faults” or “many thin bedded-parallel igneous intrusions”.
- Shows representative dip directions and dip amounts where possible.
- Is neat and easy to read.

*A bad sketch map:*

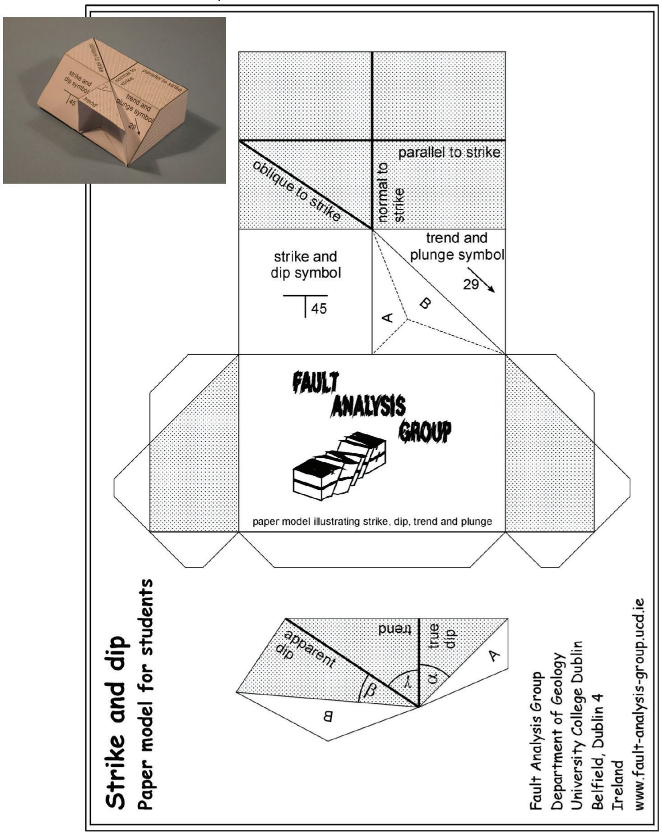
- Is the same shape and form different from the original map.
- Does not have grid lines numbered, has no scale, and it is hard to tell which bit of it refers to what part of the original map.
- Uses colours and ornament that do not relate to those of the original map, used too many colours or uses ornaments without a key.
- Does not have a key.
- Is a detailed reproduction of the original map, right down to the drift in the stream valleys. (if you want a smaller reproduction of the map, use a photocopier)
- Retains all the stratigraphic detail of the original.
- Does not highlight the features of the map as a whole: any analysis of this small map is as difficult as, if not harder than, analysis of the original. The idea is to sort out what is important and show these features on your sketch.
- Does not give any clue to topography.
- Does not show dip or even dip directions.
- Has no helpful annotation.
- Is messy, has imprecise line work and is generally hard to read.

**NOTE:**
The information, hints and tips provided in this topic should also be used in the study of Geology in grades 11 and 12.

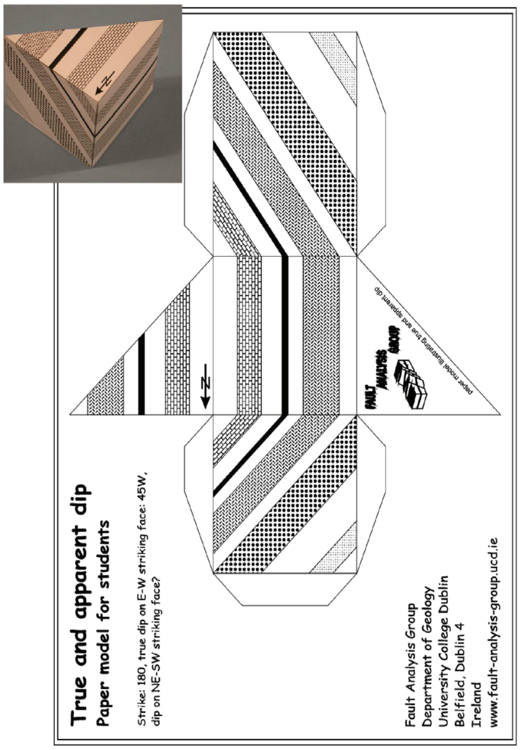
Shown in the table below are 2 paper models of strike and dip and true and apparent dip. Use these to practice making models of your geological maps.

These and other paper models are available from:
Fault Analysis Group, Department of Geology, University College Dublin, Belfield, Dublin 4, Ireland
www.fault-analysis-group.ucd.ie

**3 dimensional model of strike and dip**




**3 dimensional model of true and apparent dip**



| Topic 4: Sources of Error | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.8** Determine when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent.<br><br>**9.1.1.6** Identify and communicate sources of unavoidable experimental error. |
| **Key question** | What are the main sources and types of Errors in Science investigation? |
| **Learning objectives** | At the end of this topic, students can:<br>Evaluate sources of error in a systematic manner and apply these in different situations. |
| **Vocabulary** | Systematic error, random error, mistake, gross error |
| **Knowledge** | • Sources of error<br>• Types of error<br>• Difference between error and mistake |
| **Skills** | • Differentiate between error and mistake and apply these correctly is identified situations.<br>• Contrast the types of error as systematic or random in different scientific situations and contexts |
| **Attitudes and values** | • Develop open-mindedness and accept that making errors is an unavoidable part of scientific process. |
| **Teaching and Learning strategies** | Teacher is adviced to make students understand that making errors in science activities is part of scientific learning process and must be addressed or proven. This is done through measurements which makes it quite different to normal daily errors or mistakes. |
| **Assessment** | 1. Demonstrate understanding of sources and types of error through scientific experiment. |
| **Materials** | Handouts/notes on sources and types of error, sources of error worksheet. |

## Content Background

The main reason for making this subject as a topic of concern is because it concerns science education, so it twill enlighten teachers about workings of science, including the origin of errors, and by using historical sources.

If a teacher becomes convinced that making errors is an unavoidable part of scientific process, and that, contrary to critics, science remains a reliable source of knowledge and an ethical profession, the teacher will convey these ideas to students. The historical method is indispensable for teaching the nature of science, and when combined with investigative experimentation it also improves learning of the scientific content, increases an interest in experimentation, and makes learning of science more enjoyable

**What is an error?**

An **error** (from the Latin **error**, meaning "wandering") is an action which is inaccurate or incorrect. In some usages, an **error** is synonymous with a **mistake**. In statistics, "**error**" refers to the difference between the value which has been computed and the correct value.

**Types and Sources of Error**

Whenever you conduct an experiment or take part in the engineering design process you will have potential sources of error. Sometimes it's difficult to understand what sources of error are, so this should help!

First of all, when we talk about "sources of error" we are not talking about mistakes that were made in your project. If you made a mistake the best thing to do would be to go back and fix it. Sometimes that's not an option, because a mistake was made that influenced everything else and you don't have time to go back and do it all again. If that's the case, then you definitely want to explain that in your Mission Folder.

But this kind of mistake is not considered a "source of error." Instead, sources of error are essentially sources of uncertainty that exist in your measurements. Every measurement, no matter how precise we might think it is, contains some uncertainly, simply based on the way we measure it. **In fact there are two main types of "error" or "uncertainty":**

1. Systematic
2. Random

**Systematic errors affect the accuracy of a measurement.** They cannot be corrected with repeated measurements because they will always exist. They can be caused by faulty calibration of an instrument, poorly maintained instruments, or even faulty reading of the instrument by a person.

**Random errors are a bit different.** They affect the precision of a measurement. Random errors are caused by problems like reading the measurement between two lines on a measuring device or if the reading fluctuates. These types of errors can be reduced by conducting multiple measurements.
This is a very basic description of the types of error and sources of error in general. Just remember, sources of error are not mistakes that were made in your project, so when you have to discuss "sources of error" don't respond with something like "We didn't do anything wrong. Everything worked." This should be a discussion about uncertainty and what uncertainties existed in your measurements.

*Try answering the questions in these 4 scenarios*

**Sources of Error Worksheet**
Here you will have the chance to identify sources of error in given situations. First, let's make sure you understand the type of error you may encounter:

- What type of error influences the accuracy of your measurements and can come from faulty calibration of an instrument?.........................................................................................
- What type of error influences the precision of your measurements and can be limited by taking repeated measurements?............................................................................................

OK, let's take a look at some scenarios. After each one, you will identify what the sources of error might have been. Remember: Sources of error are not mistake made by the observer; rather they are possible sources of uncertainty.

Scenario 1:
A group is working on finding the mass of an unknown substance. They are using a digital balance. The first time they take the measurement the balance reads "2.5g." They try again and the balance reads "2.6g." They take one final reading and balance reads "2.5g." They find the mean mass by adding up the values and dividing by three (the number of measurements taken). Their final answer for the mass of the substance is 2.53g.

What are the possible sources of errors for this measurement?
.................................................................................................................................................

Scenario 2:
A group is trying to find the volume of a given liquid. To do this, they are using a graduated cylinder that is graduated by milliliters. They pour the substance into the graduated cylinder and take their reading. One group member says there are 25.5mL. Another group member says it's 25mL exactly and a third group member says they think it's 25.6mL.

What are the possible sources of error for this measurement?
..........................................................................................................................................................

Scenario 3:
A group is working on conducting a survey of their classmates to see if students prefer having lunch before noon, at noon, or after noon. They give their survey to five people. The results they find are that all five students prefer having lunch after noon. The group concludes that all students prefer having lunch after noon.

What are the sources of error in this study?
..........................................................................................................................................................

Scenario 4:
A group of students is working on tracking the growth of a plant over an entire month. Each day one member of the group needs to measure the height of the plant and record it in the group's log book. At the end of the month the groups looks at their data and notices that the numbers went up every day except one where the number went down, but then went up again the next day.

What are the sources of errors for the tracking of the plant growth?
..........................................................................................................................................................

**Summary**
Common **sources of error** include instrumental, environmental, procedural, and human. All of these **errors** can be either random or systematic depending on how they affect the results. Instrumental **error** happens when the instruments being used are inaccurate, such as a balance that does not work

Other information and examples of sources of error are described in the table below.

| | |
|---|---|
| What are 3 sources of error in an experiment?<br>Types of **experimental Errors** are normally classified in three categories: systematic **errors**, random **errors**, and blunders.<br>Systematic **errors** are due to identified causes and can, in principle, be eliminated. **Errors** of this type result in measured values that are consistently too high or consistently too low. | What are the 3 types of errors in science?<br>Three general types of errors occur in lab measurements: **random error**, **systematic error, and gross errors**. Random (or indeterminate) errors are caused by uncontrollable fluctuations in variables that affect experimental results. |
| What is random error example?<br>**Random errors** in experimental measurements are caused by unknown and unpredictable changes in the experiment. ... **Examples** of causes of **random errors** are: electronic noise in the circuit of an electrical instrument, irregular changes in the heat loss rate from a solar collector due to changes in the wind. | What are some examples of experimental errors?<br>**Melting point results from a given set of trials is an example of the latter.**<br>Blunders (**mistakes**). ...<br>Human **error**. ...<br>Observing the system may cause **errors**. ...<br>**Errors** due to external influences. ...<br>Not all measurements have well-defined values. ...<br>Sampling. |

| | |
|---|---|
| What are examples of systematic errors?<br>Systematic Error Example and Causes<br><br>Typical causes of systematic error include observational error, imperfect instrument calibration, and environmental interference. For example: Forgetting to tare or zero a **balance** produces mass measurements that are always "off" by the same amount. | What type of error is human error?<br>**Human error** is an unintentional action or decision. Violations are intentional failures – deliberately doing the wrong thing. There are three **types** of **human error**: slips and lapses (skill-based **errors**), and mistakes. These **types** of **human error** can happen to even the most experienced and well-trained person. |
| What are the four types of errors?<br>Instrumental **errors** occur due to wrong construction of the measuring instruments. These **errors** may occur due to hysteresis or friction. These **types of errors** include loading effect and misuse of the instruments.<br>...<br>**Systematic Errors**<br>Instrumental **Errors**.<br>Environmental **Errors**.<br>Observational **Errors**.<br>Theoretical **Errors** | How do you minimize errors?<br>**Minimization of Errors**<br>Calibration of apparatus: By calibrating all the instruments, **errors** can be **minimized** and appropriate corrections are applied to the original measurements.<br>Control determination: standard substance is used in experiment in identical experimental condition to **minimize** the **errors**. |

| Topic 5: Using Mathematical Functions in Science | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.3** Analyse situations and solve problems that require combining and applying concepts from more than one area of science. |
| **Key question** | Why is understanding mathematical function important is science learning? |
| **Learning objectives** | At the end of this topic, students can:<br>• Apply knowledge of properties of mathematical functions in solving science problems. |
| **Vocabulary** | Mathematical functions, function, function notation, |
| **Knowledge** | • Understanding mathematical functions in science<br>• Importance of mathematical functions in science |
| **Skills** | • Application of mathematical functions in science lessons<br>• Critical thinking<br>• Problem-solving |
| **Attitudes and values** | • Appreciate the fact that mathematical functions are applicable in science learning, especially space science, physical science and biological science. |
| **Teaching and Learning strategies** | • Teacher is encouraged to identify science topics that require applications of mathematical functions and consult mathematics teachers if need be. |
| **Assessment** | 1. Demonstrate understanding of how to apply mathematical function (applied mathematics) in selected science assignment/problem. |
| **Materials** | Handouts, calculators, textbooks |

## Content Background

In 1964 the National Institute of Standards and Technology (NIST), Cambridge University, published the Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables, edited by Milton Abramowitz and Irene A. Stegun. That 1046-page tome proved to be an invaluable reference for the many scientists and engineers who use the special functions of applied mathematics in their day-to-day work, so much so that it became the most widely distributed and most highly cited NIST publication in the first 100 years of the institution's existence. The success of the original handbook, widely referred to as "Abramowitz and Stegun" ("A&S"), derived not only from the fact that it provided critically useful scientific data in a highly accessible format, but also because it served to standardize definitions and notations for special functions.

Modern developments in theoretical and applied science depend on knowledge of the properties of mathematical functions, from elementary trigonometric functions to the multitude of special functions. These functions appear whenever natural phenomena are studied, engineering problems are formulated, and numerical simulations are performed. They also crop up in statistics, financial models, and economic analysis. Using them effectively requires practitioners to have ready access to a reliable collection of their properties.

### Function notation

A **function** is a rule for transforming an object into another object. The object you start with is called the **input**, and comes from some set called the **domain**. What you end up with is called the **output**, and it comes from some set called the **codomain**. There is a standard and very convenient notation for functions.
For example, we write the function $y = x^2$ as

$$f(x) = x^2.$$

This is read as '*f* of *x* is equal to $x^2$'. To calculate the value of the function for some input *a,* we simply substitute *a* for *x* in the formula for *f*. For example, for this function, we have

$f(3)=3^2=9$, $f(0)=0$, $f(-2)=4$, $f(a)=a^2$, $f(x+2)=x^2+4x+4$.

We are now distinguishing between the function *f (x)* and its graph *y= f (x).* a function can be given by a rule such as

$$f(x) = \frac{x^3 \sin x}{(x-2)^2}, + x \quad \text{for } x \neq 2.$$

We can easily calculate values of this function, even though drawing its graph may be quite difficult. This new way of writing function is called function notation, and was introduced to mathematics by Leonhard Euler in 1735. It is now completely standard.

**Exercise**

For the function $f(x) = \frac{x^2}{2} + x$ find

a. $f(3)$

b. $f(a+h)$.

| Topic 6: Theories that can be Proven as Mistaken or Fraudulent | |
|---|---|
| **Content standard** | Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them. |
| **Benchmark** | **10.1.1.8** Determine when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent. |
| **Key question** | 1. Why do scientists regard theories as the basis for scientific discoveries and inventions of tools and technology? |
| **Learning objectives** | At the end of this topic, students can:<br>• Evaluate the importance of theory in the study of science in relation to the inventions of tools, devices and the scientific phenomenon. |
| **Vocabulary** | Theory, fraudulent, general theory of relativity (GTR), non-veridical theory, natural phenomena, |
| **Knowledge** | • Theories that can be proven as mistaken or fraudulent<br>• Examples of theories such as the phlogiston versus oxygen, fluid model of energy and<br>• electricity and Newton versus Einstein theories of gravitation.<br>• Importance of theories in the study of science and natural phenomena |
| **Skills** | • Analyse different theories in world history.<br>• Evaluate different scientific theories and make links to their practical use in the study of<br>• science today.<br>• Apply personal experience and knowledge to real classroom situations. |
| **Attitudes and values** | • Make professional judgement based on the information provided in different theories in<br>• history and in today's world of science and technology.<br>• Value the importance of theories in human endeavour to scientific discoveries in the past and their applications today. |
| **Teaching and Learning strategies** | Teacher to research and provide information for students on different theories in science including those provided in this topic. Also let students research and learn more about different theories and present individual or group reports on these. |
| **Assessment** | 1. Students research and present findings on other theories which have either been proven as fraudulent or mistaken. |
| **Materials** | Library books, handouts, research findings. |

## Content Background

Science gives us understanding of the world. It typically does this through explanations that apply a variety of representational devices – such as theories, models and diagrams – to particular phenomena. (We will not here be concerned with understanding from other sources.) For instance, Newton's theory of gravitation is used to understand the motions of the planets, while diagrams of the citric acid cycle are used to understand why human bodies produce carbon dioxide.

To understand a phenomenon, then, we typically need a representational device of the right kind which we then have to connect to the phenomenon in the right way. In this topic, we will be interested in the first of these two elements: when is a representational device "of the right kind" to produce understanding of the phenomena to which it can be applied? After all, not all devices are equal in this respect.

The theory that the planets are pushed by angels produces less understanding of their motion than does Newton's theory. What virtue does Newton's theory have that the angelic theory lacks? One possible answer is that Newton's theory is true, or at least approximately true, while the angelic theory is false. There simply are no supernatural creatures pushing the planets, and that is why no amount of angelology will give us any understanding of the appearance of the night sky.

We illustrate our claims using three case studies: phlogiston theory versus Einstein's general theory of relativity; and fluid models of energy and electricity in science education.
oxygen theory for understanding of chemical phenomena; Newton's theory of gravitation versus

**1. Chemistry: phlogiston versus oxygen**

Phlogiston theory entered the scene in the early eighteenth-century, when chemistry was still based on the Aristotelean ontology of the four elements earth, water, air and fire. It differed from modern chemistry in two important ways:

- It was predominantly qualitative rather than quantitative; and
- It t focused on the properties of substances, not on their composition.

The elements of air and fire were most difficult to deal with experimentally, and investigating different gases (types of air) became an important field of research: pneumatic chemistry. One of the most successful scientists in this field was Joseph Priestley, who played a central role in the development of pump had shown that combustion is crucially dependent on air, since a flame dies out in vacuum; (The same appeared to hold for life, since living mice died when put in a vacuum).

**2. Gravitation: Newton versus Einstein**

Our second example of a non-veridical theory proving understanding is Newton's theory of gravitation. Newton's theory was extremely successful and unchallenged for more than two hundred years, from its inception in 1687 until 1915 when it was superseded by Einstein's general theory of relativity (GTR). In GTR, there are no attractive forces between masses; instead, gravitational phenomena result from the specific characteristics of the local space-time structure. As we will focus on the theory of gravitation, the most important ontological change is the abandonment of the Newtonian concept of gravitational force.

Today, physicists accept Einstein's GTR as the true theory of gravitation: although they admit that future developments may require modification of GTR, its predictions have so far been verified with astonishing precision.

**3. Fluid models of energy and electricity**

As a final example of representational devices that are non-veridical yet provide understanding, we briefly discuss fluid models used in physics education to promote students' understanding of the concepts of energy and electricity. Although today we know that representation of energy or electricity as a substance is fundamentally wrong, there are certain advantages in using fluid models to teach children and students about energy and electricity, giving them a basic understanding of these concepts. Such substance-models of energy and electricity have historical precursors. Around 1750 Benjamin Franklin developed an influential one-fluid model of electricity that explained and predicted a variety of electrical phenomena (see Hankins 1985, 62-67). Around 1800 the caloric theory, which represented heat as an indestructible fluid of minute particles, was the most prominent theory of heat (see Psillos 1999, 115-125). Although a mechanical theory of heat was also available, the caloric theory had been worked out in more detail and was generally supposed to be more successful. It was used to explain specific heats, heat flow, thermal expansion and transmission of heat across a vacuum, among other things. While there were some problems, such as the explanation of heating by friction, for half a century or more the caloric theory was a highly effective representational device for physicists. According to our theory, these theories provided understanding, just like phlogiston theory. On the veridicality condition, however, one would have to conclude that both Franklin's theory of electricity and the caloric theory of heat generated no understanding, since their core assumptions are false. To us, this seems a perverse reading of history.

But even more interesting, from our point of view, are contemporary twenty-first-century attitudes towards fluid models of energy and electricity. No physicist doubts that thinking about energy as a fluid streaming from object to object, or about electricity as a fluid stored in batteries and streaming through wires, is to have a representation that is highly non-veridical. And yet both models are widely held to provide understanding of the physical phenomena.

Conclusion

The arguments and case studies have undermined the traditionally accepted view that a criterion of representational veridicality is a necessary condition for scientific understanding. To replace this ‘veridicality condition’, we have proposed the effectiveness condition on understanding; understanding requires representational devices that are scientifically effective; where scientific effectiveness is the tendency to produce useful scientific outcomes such as;

- Correct predictions,
- Successful practical applications, and
- Fruitful ideas for further research

Finally, the feature of this condition is its contextuality: whether or not theories or models are effective, and to which degree, depends on the context in which they are used – not only on the phenomena to which they are applied but also on the skills and background knowledge of scientists who use them.

## Unit 10.3 Classifying Organisms

Among the characteristics of living things, reproduction is one of the characteristics although not necessary for an individual organism to survive. However, no individual lives forever and if the species is to survive the individuals must replace themselves before they die. This generation of new individuals are formed as a result of reproduction. The simplest form of reproduction simply involves an organism splitting in two.

| Topic : Reproductive Systems | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmark** | **10.2.2.4** Explain the inheritance of sex-linked traits in humans and use a pedigree to track the inheritance of a single trait. |
| **Key question** | • What are the types of reproductive systems?<br>• What are the types of asexual reproduction?<br>• How does the reproductive system work?<br>• Do plants and other animals have the same reproductive systems as humans? |
| **Learning objectives** | At the end of the topic, students can:<br>• Understand the importance of reproduction<br>• Distinguish between asexual and sexual reproduction and the advantages and disadvantages involved in these.<br>• Identify the different types of asexual reproduction.<br>• Identify on diagrams , the male and female reproductive systems |
| **Vocabulary** | Asexual reproduction, Sexual reproduction |
| **Knowledge** | • Sexual reproduction is the process involving the fusion of two nuclei to form a zygote and the production of genetically dissimilar offspring<br>• Asexual reproduction is the process by which genetically identical offspring are produced from one parent. |
| **Skills** | • Describe reproduction in unicellular and multicellular organisms.<br>• Evaluate the function of the male and female reproductive systems including the menstrual cycles of females.<br>• Draw diagrams of the male and female reproductive system of humans. |
| **Attitudes and values** | • Respect their classmates' opinions.<br>• Work cooperatively in group discussions<br>• Value the importance of having sexual reproduction lessons |
| **Teaching and Learning strategies** | • Research the different types of asexual reproduction.<br>• Demonstrate using available resources the different types of asexual reproduction |
| **Assessment** | 1. Differentiate between the different types asexual reproduction. |
| **Materials** | Handouts, Textbooks, pictures |

## Content Background

### Reproduction

Reproduction is defined as a biological process in which an organism gives rise to young ones (offspring) similar to itself. The offspring grow, mature, and in turn produce new offspring. Thus, there is a cycle of birth, growth, and death. Reproduction enables the continuity of species, generation after generation.

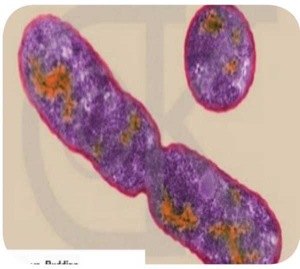
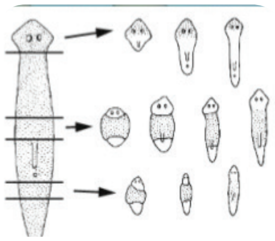
### Types of reproduction

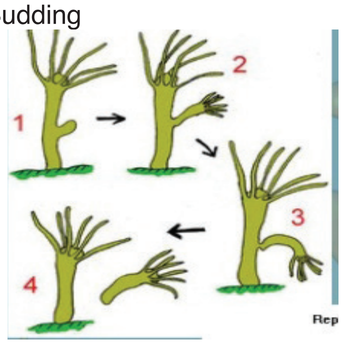
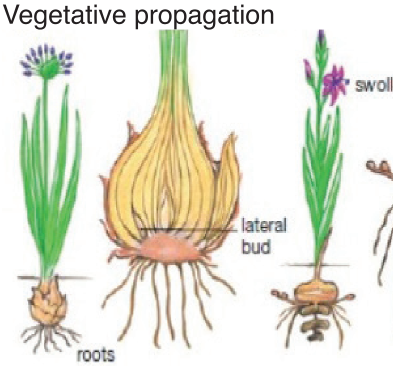
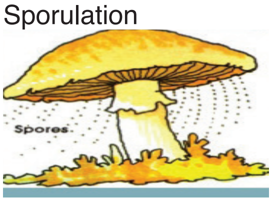
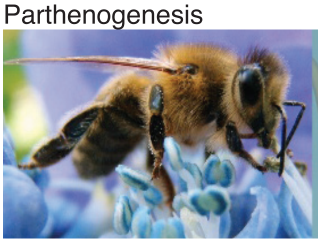
All living organisms reproduce. There are two types of reproduction;

**1. Asexual reproduction**

Asexual reproduction occurs when a single individual is involved. Unicellular organisms such as bacteria and protists as well as some plants, fungi and a few animals reproduce asexually. That is, they reproduce by mitotic divisions of producing offspring that are identical to their parents – clones. In multicellular organisms the new individual will arise from a cellular division of an ordinary body cells (a somatic cell). Many organisms that reproduce asexually have the ability reproduce sexually also but the occurrence of this may be rare. Organisms that reproduce asexually are found in stable environments to which they are very well suited.

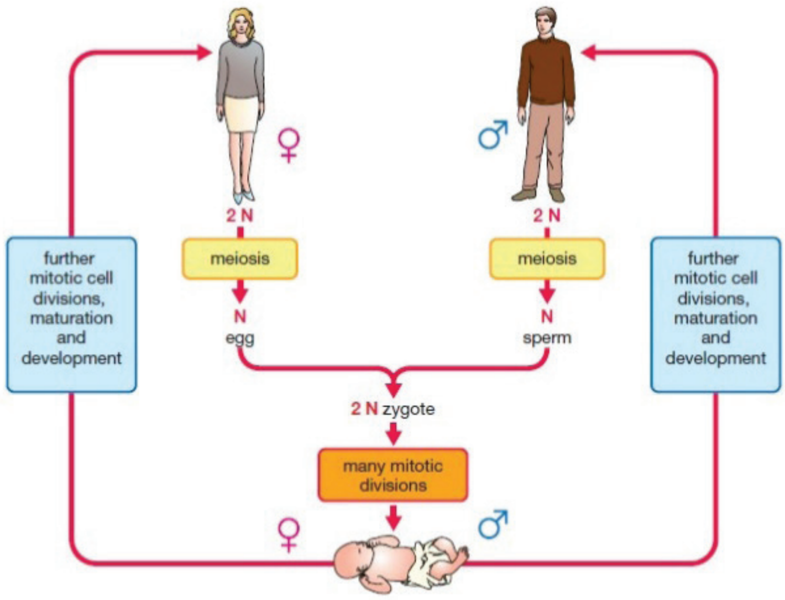
Examples of Asexual reproduction include; Fission, Fragmentation, Budding, Regeneration, Vegetative propagation, and Spore formation.

| Type of Asexual reproduction | How it occurs |
|---|---|
| Binary Fission  | Fission is common among unicellular organisms such as bacteria and *Amoeba.* It occurs after the mitotic division of the nucleus when the parent cells splits into two equally sized daughter cells forming a new organism. It is further divided into two types – Binary Fission, and Multiple Fission.<br><br>In binary fission, the single cell divides into halves. A few organisms that divide by binary fission are bacteria and amoeba. In amoeba, cell division or splitting of cells can take place in any plane, it can also occur in one particular axis. For example, Leishmania (a parasitic flagellated protozoan), which causes kala azar in humans, divides only longitudinally. Leishmania has whip-like flagella at one end of the cell. Cell division occurs in relation to these flagella.<br><br>In Multiple fission, a single cell divides into many daughter cells simultaneously. Examples are Plasmodium and Amoeba. |
| Fragmentation  | It is a form of Asexual reproduction in which an entirely new organism is formed from a fragment of the parent. It occurs in Multicellular organisms, whose body organisation is fairly simple. Examples of this are; annelids, starfish, fungi, lichens, and some algae such as spirogyra. The filaments of spirogyra, upon maturation, break into small pieces or fragments, which grow into new individual. |
| Regeneration | Regeneration can be defined as the natural ability of living organisms to replace worn out parts, repair or renew damaged or lost parts of the body, or to reconstitute the whole body from a small fragment during the post embryonic life of an organism. |

| | |
|---|---|
| Budding<br> | In budding, the parent cell or body gives out lateral outgrowth called the bud. It is seen in certain fungi and multicellular animals. The nucleus divides and one of the daughter nuclei passes into the daughter cell. The bud grows in size while being attached to the parent body. It then gets separated from the parent by the formation of a wall. It finally falls off and germinates into a new individual. This, budding results in the formation of daughter cells of unequal sizes that later grow to adult size. For example, yeast, fungus, and Hydra, which is a multicellular animal. In the case of hydra, the daughter hydra even develops mouth and tentacles develop around the mouth before being detached from the parent body. |
| Vegetative propagation<br><br> | Plants raised by vegetative propagation can bear flowers, earlier than those produced from seeds. Such methods also make possible the propagation of plants such as banana, orange, rose, and jasmine that have lost their capacity to produce seeds. Another advantage of vegetative propagation is that all plants produced are genetically similar to the parent plant.<br>Some examples of vegetative propagation are:<br>(a) By Leaf – buds produced in the notches along the margin of plants fall on the soil and develop into new plants. Example, bryophyllum (cactus and doctor leaf family).<br>(b) By Stem – Runners are stems that grow horizontally above the ground. They have nodes where buds are formed. These buds grow into new plant.<br>(c) By Roots – New plants will grow out of swollen, modified roots called tubers. Buds develop at the base of the stem and then grow into new plants.<br>(d) By Stem Cutting – cuttings are part of the plant that is cut off from the parent plant. Shoots with leaves attached are usually used. New roots and leaves will grow from the cutting. The shoots is cut at an angle.<br>(e) By Layering – In layering, a shoot of a parent plant is bent until it can be covered by soil. The tip of the shoot remains above the ground. New roots and eventually a new plant will grow which can then be separated.<br>(f) By Grafting – In Grafting, two (2) plants are used to develop a new plant with combined traits from the 2 parent plants. In grafting, the scion is the above ground part of one plant. The scion is attached to the stock which is the rooted part of the second plant. |
| Sporulation<br> | Spores are formed by fungi and are often contained within a structure known as a sporangium which will disintegrate releasing the spores into the environment. When a spore lands in a suitable environment it will germinate forming a new fungus. Spores are formed by budding. Bacteria, algae, fungi, ferns and mosses develop spores which detach from the parent and develop into new individuals. |
| Parthenogenesis<br> | The development of an unfertilised egg into a new individual that is a clone of the parent. In order to obtain the needed diploid set of chromosomes the egg will often duplicate by mitosis and then fuse to give the egg two sets of chromosomes. Bees. Wasps, ants and some species of birds and lizards are parthenogenetic. |
| Cloning | Mitotic division that results in a development of a clone with the exact genetic make-up |

**2. Sexual reproduction**

Sexual reproduction occurs when two individuals are involved. In animals, sperm and eggs are known as gametes. The gametes contain half the number of chromosomes as a normal cell (23 in humans). This is referred to as **haploid.** When the nuclei of both gametes fuse, the fertilised egg cell contains the normal number of chromosomes (46 in humans). This is referred to as **diploid.** Sexual reproduction relies on gametes produced by meiosis which are developed in the gonads. Female gonads are ovaries which develop egg cells (ova). Male gonads are testes which produce sperm cells. The joining of haploid sperm cell and haploid egg cell results in **diploid zygote**. This can be either internal or external fertilisation.




When eukaryotes reproduce sexually, offspring receive genetic material from two parents. Meiosis and fertilisation shuffle and reshuffle genes, generation lots of genetic diversity. The offspring of sexually reproducing organisms are never identical to either their parents or their siblings (except for identical twins).

**Sexual Reproduction in Animals**

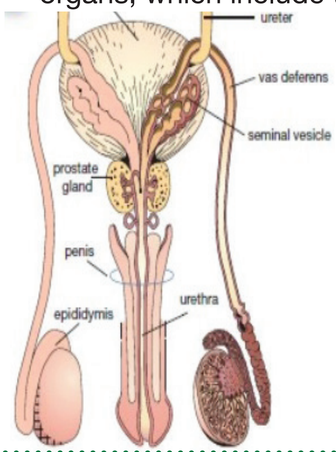
In animals, gamete cells are produced in special organs called gonads. The gonads that produce the male gamete (sperm) are the testes while those producing female gametes (egg) are the ovaries. Each gamete will be in the haploid state (n). In humans, the diploid number is 46 (2n) while the haploid number for each gamete is 23 (n). this ensures that the number of chromosomes formed after the fertilization remains 46 instead of doubling after each fertilization.

## The male reproductive system

Most animals have two sexes; male and female. Each sex has its own unique reproductive system. They are different in shape and structure, but both are designed to produce, nourish and transport either the egg or sperm.

The male sex organs are both inside and outside the pelvis. The male genitals include:

- Testes
- Duct systems, which is made up of the epididymis and the vas deferens , accessory glands/ organs, which include the seminal vesicles, Cowper's glands and prostate gland
- 



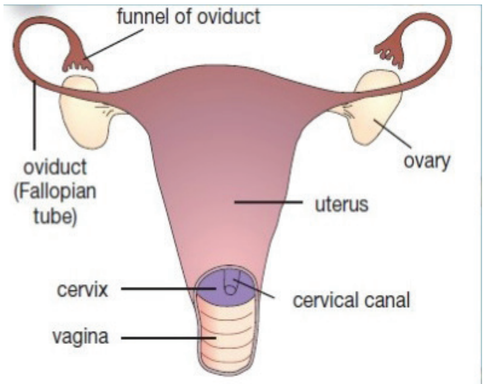

- Two paired testes which are composed of many tubules. Lining the outer region of these tubules are sperm precursor cells. Mitotic divisions of these cells produce spermatocytes each of which divides to produce four sperm cells
- From the testes the sperm pass into the epididymis. Here the sperm complete maturation and are stored for up to six weeks
- During mating contractions of the vas deferens move sperm towards the urethra. On the journey secretions of the accessory glands are added forming seminal fluid. The fluid causes the sperm to become motile and provides them with nutrition

The organs of the male reproductive system are specialized for the following:

- To produce, maintain and transport sperm.
- To discharge sperm within the female reproductive tract.
- To produce and secrete male sex hormones

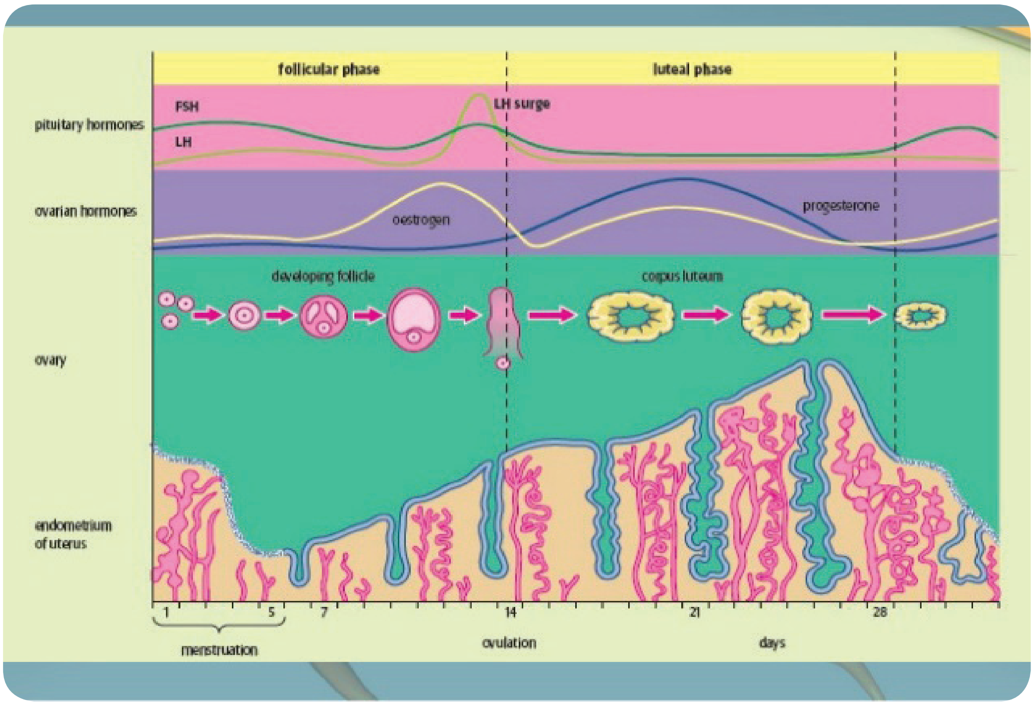
**The Female Reproductive System**

The human female reproductive system is located entirely in the pelvis. The external part of the female reproductive organs is called the vulva, which means covering.
The female internal reproductive organs are the vagina, uterus, fallopian tubes (oviducts) and ovaries.




- The vagina is a muscular, hollow tube that extends from the vaginal opening to the uterus. The muscular walls are lined with mucous membranes, which keep it protected and moist. The vagina serves three purposes. Its where the penis is inserted during sexual intercourse; it's the pathway where the baby comes  and it provides the route for the menstrual blood to leave the body from the uterus.
- The uterus is shaped like an upside-down pear, with a thick lining and muscular walls.
- The fallopian tubes connect the uterus to the ovaries. Ovaries are two oval-shaped organs that lie to the upper right and left of the uterus. They produce, store and release eggs into the fallopian tubes in the process called ovulation.

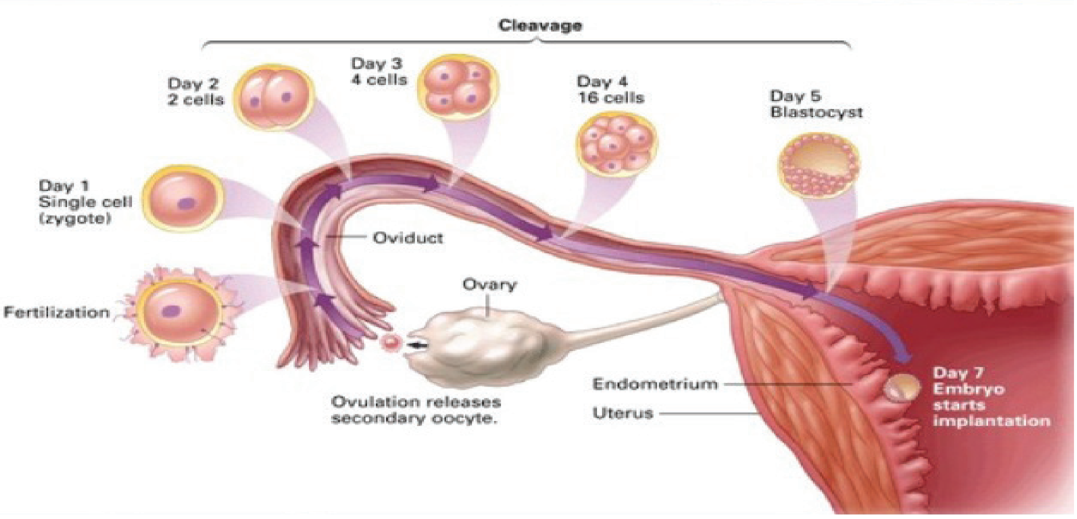
## Menstruation




Menstruation is a woman's monthly bleeding. It is also called menses, menstrual period or period. The menstrual blood is partly blood and partly tissue from the inside of the uterus. It flows from the uterus through the small opening in the cervix and passes out of the body through the vagina.

## Fertilisation

Fertilisation is the fusion of two gametes to form a zygote. It involves three events; recognition and penetration of the egg by the sperm; activation of the egg cell which initiates development and fusion of the egg and sperm nuclei.




In humans, sperms are ejaculated from the penis of the male into the vagina of the female during sexual intercourse. Before fertilization can occur, the sperm must travel through the cervix, into the uterus, and along the fallopian tube to where the egg is maturing. Fertilisation will occur if an active sperm can penetrate a suitably mature egg.

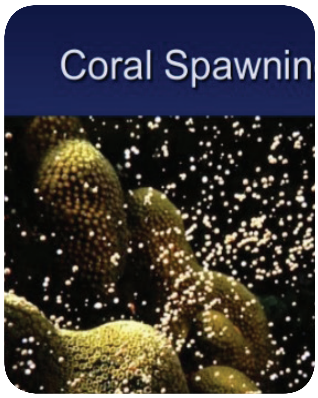
The result of the three processes is a zygote- the beginning of a new individual. A zygote is the size of the egg cell which is a very large cell. The first step after fertilisation is **cleavage.** Cleavage is a period of cell division in which the egg cell is divided into many hundreds of smaller cells. This occurs as the embryo passes down the fallopian tube into the uterus.

### Internal fertilisation

In internal fertilisation gametes fuse inside body of females. It occurs in land animals. Sperm is placed inside into female's body and must travel in moist, watery environment to reach and fertilise the egg. Sperm cannot live long so timing is critical. The critical time when egg is ready is "ready" is known as **estrous** which is controlled by hormones.

### External fertilisation

External fertilisation occurs outside the female body through fusion. It must occur in water. Eggs are laid in water and sperm shed and swim in water to fertilise the eggs. This process can be hazardous so many eggs and sperm are produced.




Therefore, to aid external fertilisation, eggs are laid and the male swims over the eggs and releases sperm over them to ensure maximum fertilisation. This is called **spawning**. For example; coral spawning

Also the male frog can hold the female as she lays eggs to ensure that sperm reached most eggs. This is called **amplexus**. For example; frogs fertilisation.

| Topic : Inherited Traits | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmark** | **10.2.2.4** Explain the inheritance of sex-linked traits in humans and use a pedigree to track the inheritance of a single trait<br>**10.2.2.5** Describe the relationships among DNA, chromosomes, genes, and the expression of traits. |
| **Key question** | 1. What is inheritance?<br>2. How does inheritance work?<br>3. What is codominant inheritance?<br>4. What is the difference between a gene and an allele?<br>5. What is meant by a dominant allele? |
| **Learning objectives** | • discuss the contributions of scientists including Gregor Mendel and his experiments with pea garden<br>• compare dominant trait to a recessive trait<br>• identify traits in themselves that are either dominant or recessive.<br>• understand the principles of the test cross |
| **Vocabulary** | Codominance, dominant , chromosomes, DNA |
| **Knowledge** | • Inheritance and types of inheritance patterns.<br>• Mendel's experiment and his laws of inheritance.<br>• Inheritance patterns can be simple or complex and involve continuous and discontinu-ous variations.<br>• Principles of testcross |
| **Skills** | • Differentiate between the different types of inheritance patterns<br>• Identify dominant and recessive traits<br>• Use pedigrees to explain dominant and recessive traits |
| **Attitudes and values** | • Value the importance of studying inheritance<br>• Appreciate how inheritance can be predicted in different organisms |
| **Teaching and Learning strategies** | 1. Research the Gregor Medel pea experiment.<br>2. In groups discuss how traits are passed to the next generation<br>3. Use pedigrees to show dominant and recessive traits in a family |
| **Assessment** | 1. Draw a diagram to explain how two brown-eyed parents can have a blue-eyed child. |
| **Materials** | Handouts, textbooks, charts |

## Content Background

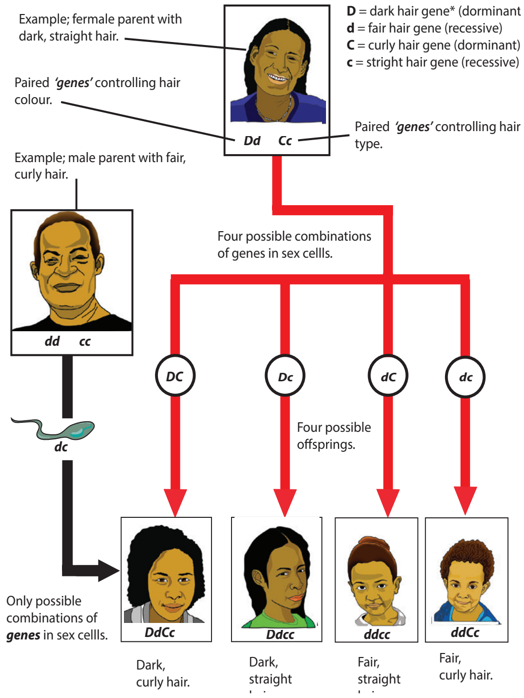
Two influences make you what you are at this moment: heredity and environment. Heredity is the set of characteristics that you inherited from your parents. Environment is the set of factors that have acted on you throughout your life.

### Inheritance

The study of inheritance or heredity is the study of the mechanisms behind the transfer of genetic materials from parents to offspring. Our characteristics such as hair, eye colour, height and many other traits are passed down from one generation to another, but why is that we don t look exactly like our parents or siblings. Did we inherit only some of the characteristics? Or did our paternal characteristics mix with our maternal ones? Scientists were not able to answer these questions until the mid-19$^{th}$ Century when an Austrian monk, Gregor Mendel carried out breeding experiments with garden pea plants and gave a series of accurate explanations for the mechanism of inheritance. These explanations which are called **Mendelian** inheritance or **Mendelian genetics** involve the **Laws of Inheritance,** and form the basis of genetic experiments today.

From these series of experiments, as well as other pea plant experiments, Mendel was able to offer an acceptable explanation of inheritance, now known as **Mendel's Laws of Inheritance.** He concluded that:

- Heredity factors are responsible for the transmission of characteristics.
- Each characteristic is controlled by a pair of factors in the cell of the organism. For example in the length of the pea plant, there is a pair of factors that dictate whether the plant will be tall or dwarf but one will be dominant to the other. This is known as **Mendel's Law of Dominance.**
- The factors in each pair will separate or segregate during gamete formation and each gamete will contain only one factor. This is known as **Mendel's Law of Segregation**
- In other experiments in which he crossed two pairs of contrasting characteristics forming resulting in dihybrid inheritance, he observed that the characteristics are distributed to the gametes independently of one another and they unite at random. This is known as **Mendel's Law of Independent Assortment.**




## The inheritance of characteristics

Chromosomes carry genetic information as a series of genes, such as the gene of the eye colour, the gene of the earlobe shape and the gene of the hair texture. Each chromosome in the nucleus of a diploid organism has a partner that carries the same genes. Such a pair of chromosomes is called an homologous pair. Each chromosome in a pair may carry alternative forms of the same gene. These alternative forms are called alleles.

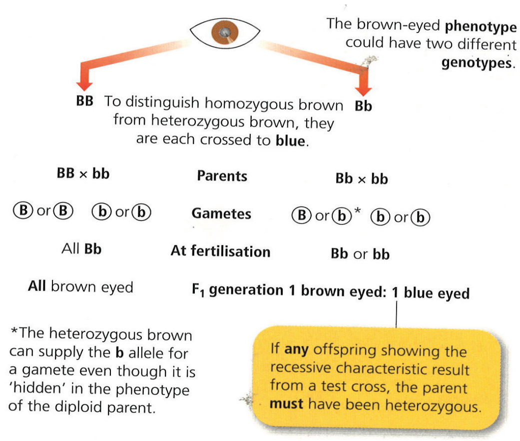
## Test Crossing

Scientists called **geneticists** study the inheritance of characteristics by carrying out breeding experiments. There is a conventional pattern for describing the results of such experiments.

Drawing out chromosomes carrying alleles of genes is time-consuming. Geneticists write out the stages of crosses using symbols to replace the chromosomes and genes. These symbols should always be identified at the start of a cross. For example

Let **B**= Brown and **b**= blue
The **capital** letter is used for the dominant allele.
Brown (B) and blue (b) are **alleles** of the gene for eye

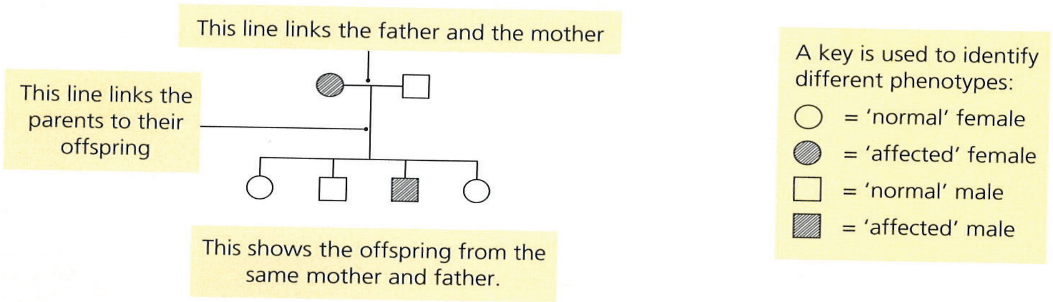
| Ration: dominant to recessive | Phenotypes of parent |
|---|---|
| 3:1 | Both heterozygous |
| 1:1 | One heterozygous, one homozygous recessive |




▲ A test cross can distinguish different genotypes with the same phenotype

The results of genetic crosses are sometimes shown as a pedigree.

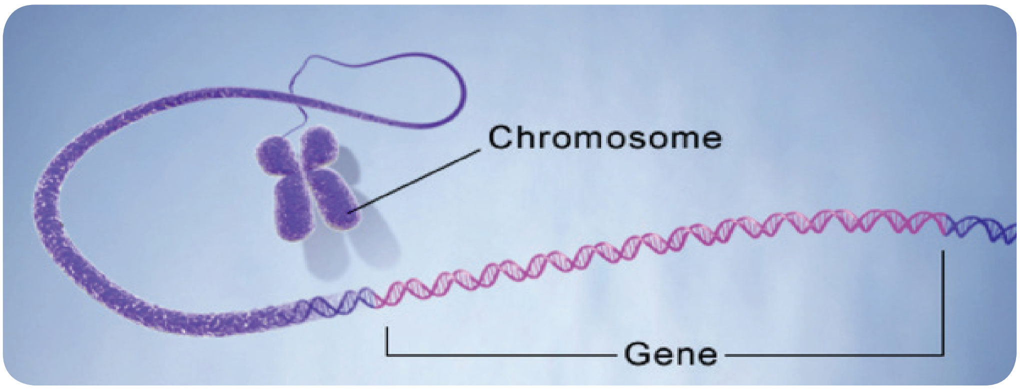
Rules for showing a pedigree (family tree)




**Relationship between Chromosomes, Genes and DNA**

When a cell is not actively dividing, its nucleus contains chromatin- a tangle of fibres composed of protein and a chemical molecule known as **deoxyribonucleic acid (DNA).**when the time comes for the a somatic cell to divide into two new cells, the DNA is duplicated via mitosis so that each new cell can receive a complete copy of all the genetic material in the 'parent ' cell.

During cell division, chromatin organizes itself into chromosomes. Each chromosome is made up of the chemical molecule known as DNA. The chromosome comprises genes- individual segments of DNA that contain the instructions needed to direct the synthesis of a protein with a specific function. Each chromosome actually contains a single immense molecule of DNA that, in humans, has a length of up to 12 centimetres when stretched out.




Credit: U.S. National Library of Medicine

Genes are made up of DNA. Each chromosome contains many genes

**What is DNA?**

Deoxyribonucleic acid (DNA) is a nucleic acid that contains the genetic instructions specifying the biological development of all cellular forms of life (and many viruses). It is often referred to as the molecule of heredity as it is responsible for the genetic propagation of most inherited traits. During reproduction, DNA is replicated and transferred to the offspring as you have learnt.

In bacteria, (prokaryotes), DNA is not separated from the cytoplasm by a nuclear envelope. By contrast, in the complex cells that make up other organisms (plants, animals, fungi and protists), most of the DNA is located in the cell nucleus. The energy generating organelles such as chloroplast s  and mitochondria also carry DNA for their own functions, as do many viruses.

Basically, DNA is a basic building block of life and it contains all the information that living things need to function correctly. For example, in humans, tis can cause variations I hair colour, affect one ability to roll one's tongue and cause heredity diseases.

Your DNA is composed of genes inherited from both your mother and father. DNA from both of your parents was combined to form the genome of a fertilised egg, then, that the egg is divided many times copying the DNA before every division until all the cells of your body were formed. As a result each cell in your body contains copies of DNA from your parents (except the red blood cells, which loose their chromosomal DNA and cannot divide and the sex cells which are haploid)

**Chromosomes**

Chromosomes are structures found in the nucleus and they carry all of the organism's genetic information. They are typically made up of proteins, DNA and RNA. When the cell is not dividing, individual chromosomes are not visible. They are coiled up into a material called **chromatin**, which can be viewed under the light microscope when stained. Individual chromosomes are only visible when the cell is about to divide and they appear as long, thin, thread-like structures 0.25 mm and 50mm in length. Each chromosome consist of two threads known as chromatids joined at the centromere.

**Genes**

Gene is the basic physical and functional unit of heredity. Genes are made up of DNA. Some genes act as instructions to make molecules called proteins. However, many genes do not code for proteins. In humans, genes vary in size from a few hundred DNA bases to more than 2 million bases. An international research effort called the Human Genome Project, which worked to determine the sequence of the human genome and identify the genes that it contains, estimated that humans have between 20,000 and 25,000 genes.

Every person has two copies of each gene, one inherited from each parent. Most genes are the same in all people, but a small number of genes (less than 1 percent of the total) are slightly different between people. Alleles are forms of the same gene with small differences in their sequence of DNA bases. These small differences contribute to each person's unique physical features.

Scientists keep track of genes by giving them unique names. Because gene names can be long, genes are also assigned symbols, which are short combinations of letters (and sometimes numbers) that represent an abbreviated version of the gene name. For example, a gene on chrome 7 that has been associated with cystic fibrosis called the cystic fibrosis transmembrane conductance regulator; its symbol is *CFTR*

| Topic : Transferring Genetic Information | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmark** | **10.2.2.7** Discuss current and potential applications and implications of biotechnologies including their effects upon personal and public decision making. |
| **Key question** | 1. What is gene transfer?<br>2. What are natural and artificial gene transfers? |
| **Learning objectives** | • Investigate how the human ability to manipulate genetic material and reproductive processes (e.g., genetic engineering, cloning, stemcell research) can be applied to many areas of medicine, biology, and agriculture. Evaluate the risks and benefits of various ethical, social, and legal scenarios that arise from this ability.<br>• Explain the basic process of bacterial transformation and how it is applied in genetic engineering.<br>• Explain how developments in technology (e.g. gel electrophoresis, gene sequencing, bioinformatics, DNA fingerprinting, genetic amplification, proteinomics) are being used to identify individuals based on DNA as well as improve the ability to diagnose and treat genetic diseases |
| **Vocabulary** | Genetic engineering, |
| **Knowledge** | • The development of technology has allowed us to apply our knowledge of genetics, reproduction, development, and evolution to meet human needs and wants.<br>• Artificial gene transfer<br>• Natural gene transfer |
| **Skills** | • Evaluate the process of gene transfer<br>• Make prediction<br>• Make models of gene transfer |
| **Attitudes and values** | • Respect human rights and responsibilities<br>• Open – minded during discussions and sharing of opinions and scientific views on artificial and natural gene transfers. |
| **Teaching and Learning strategies** | Teacher needs to inform students when expressing their views on sensitive scientific discoveries of stem cells and examples of gene transfer. Teacher should also prepare students notes through research or allow them to carry out research themselves. |
| **Assessment** | 1. Carry out research on artificial and natural gene transfer mechanics and present findings to class. |
| **Materials** | Library books and research, handouts, diagrams of artificial and natural general gene transfers, including physical and chemical means. |

## Content Background

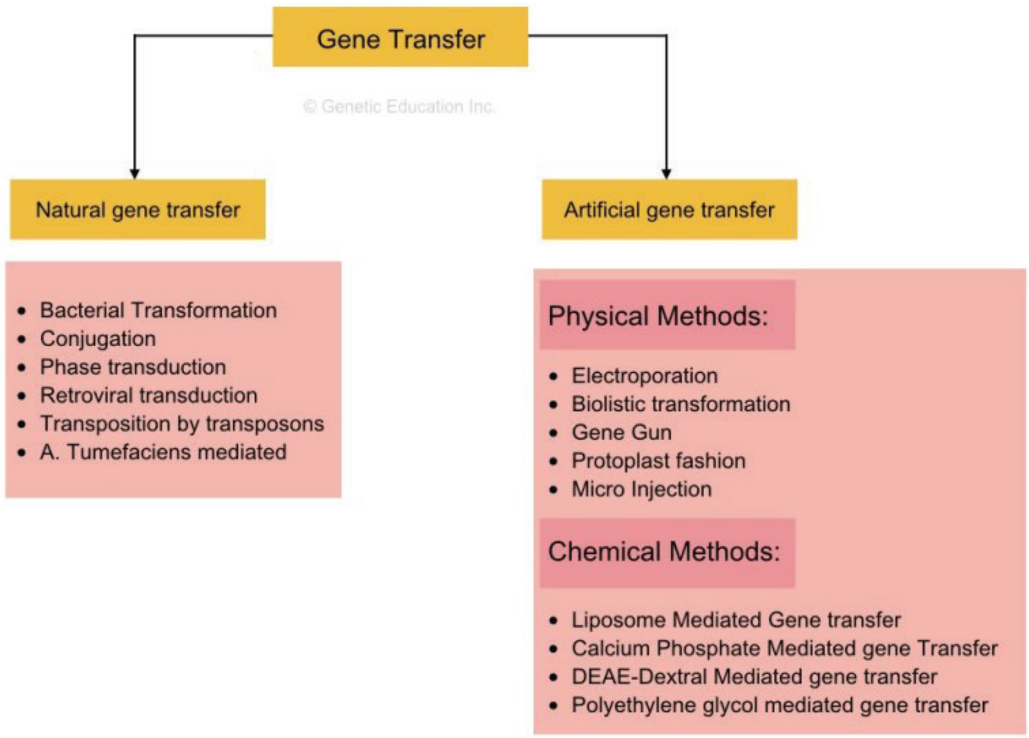
**What is gene transfer?**

A genetic engineering technique to transfer genes using vectors from one organism to another or from one cell to another in order to treat disease, construct GMO and economically important organisms are known as gene transfer. The first evidence of gene transfer was reported in bacteria by Frederick Griffith in 1928. He had named it a transformation. In 1944, Avery had demonstrated that the material transfer between bacteria during transformation is the nucleic acid (DNA) which was later validated by Hershey and Chase in 1952. Although the exogenous gene transfer in a eukaryotic cell (in vitro) was demonstrated by Rogers in 1970.

**Types of gene transfer**

Usually, the gene transfer techniques used in various applications can be categorized into two broader categories.

- Natural methods of gene transfer
- Artificial methods of gene transfer




**The natural mode of gene transfer**

In this technique natural agents like live cells, bacteria, other DNA molecules and viruses are used to transmit genes. Some of them are:

1. Bacterial transformation
2. Conjugation
3. Phage transduction
4. Retroviral transduction
5. Transposition
6. Agrobacterium tumefaciens mediated gene transfer

**The artificial method of gene transfer:**
In this technique, an exogenous gene is transmitted to another cell or organism using artificial means either physical or chemical agents. Some of the common artificial technique are:

**Physical methods**
- Electroporation
- Biolistics transformation
- Gene gun
- Protoplast fusion
- Microinjection

**Chemical methods**
- Liposome mediated gene transfer
- Calcium phosphate mediated gene transfer
- DEAE- Dextran mediated gene transfer
- Gene transfer using polyethylene glycol

Yet another classification of gene transfer is based on which organism it affects. It can be categorized into ***horizontal gene transfer*** and ***vertical gene transfer.***

**Horizontal gene transfer vs vertical gene transfer:**

When gene transfer occurs between *two unrelated individuals or organisms*, this type of gene transfer is known as the horizontal gene transfer. It is also called the lateral gene transfer method. Usually, it is commonly observed between prokaryotic and eukaryotic cells. The origin of antibiotic resistance in bacteria is the classic example of the horizontal gene transfer by natural means.

On the other side in the vertical method of gene transfer, the genes are transmitted from parents to their offsprings.This means the transfer of genetic material or genes from one cell to another or one organism to another related organism is known as the vertical mode of gene transfer. Several examples of horizontal gene transfer are:

***Transformation:*** Alteration in a gene by uptaking genetic material from unrelated organisms is known as transformation. It is used in transformation experiments to transmit genes in bacteria to infect a host.

***Transduction:*** Transfer of genetic material from one bacterium to another by the virus or phase is known as transduction.

***Conjugation:*** The gene transfer of one cell to another using the bacterial plasmid from donor to recipient cell is known as conjugation.

***Transposable elements:*** The transposons or transposable elements are the mobile genetic sequences that can carry a gene or DNA and can transfer it to other unrelated cells.

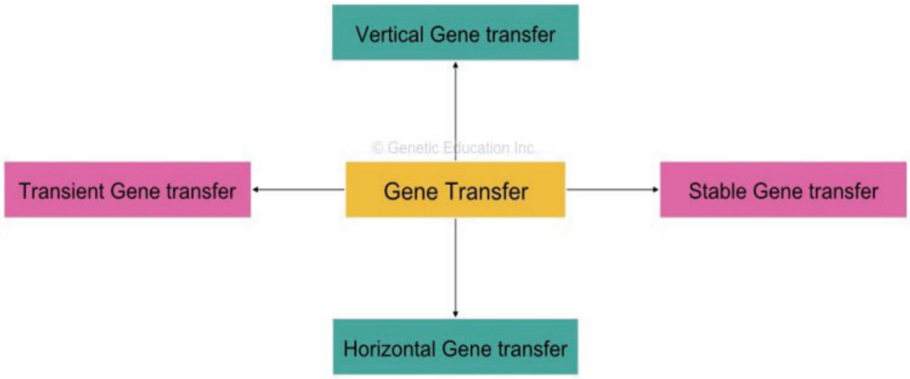
Cervical cancer caused by the HPV is an example of horizontal gene transfer in which the infected cell transmits the genetic material to another cell and spreads cancer.
On the other side,The gene transfer from one related cell to another or parental organisms to their progenies is known as a vertical mode of gene transfer.

The process of reproduction or the sexual mode of reproduction is a type of vertical mode of gene transfer. Crossbreeding in plants is the most common example of vertical gene transfer used by scientists for a long time. These two plants are sexually reproduced or crossed to produce a superior quality plant species. Further to this, the meiosis and mitosis cell division process is a way of vertical gene transfer in which genetic material is inherited from one identical cell to another.
Infection of HIV from mother to child is an example of it. Here the infected patient or cell inherited the genetic material of HIV along with their own to their offspring. Resultantly, the progeny of the baby got infected by HIV.

**Transient vs stable gene transfer or transfection:**

In the transient type of gene transfer, the foreign genetic material is never incorporated into the host genome and thus can't be inherited to offspring.
On the other side, in the stable gene transfer, the gene or foreign DNA inserts into the host genome and transmits into the offspring.
The transient gene transfer is performed to produce a temporary high level of gene expression and thus it is limited to somatic cells.
While in the stable gene transfer, once the gene is incorporated into the host genome it may express normally, transmit to offspring and express normally in them too.

It is usually performed on germ cells.




**Artificial Gene transfer techniques:**

**Physical Gene transfer methods:**

Electroporation, biolistics transformation, gene gun, protoplast fusion and microinjection are some common physical gene transfer techniques used often in genetic engineering experiments.

***Electroporation:***

The electroporation technique is one of the commonest and successful methods used so far by scientists. In this method, the gene of interest or the DNA is transferred into the target cell under the influence of an electrical pulse.

Under the pulse electric current, pores are created in the cell wall or the plasma membrane of a cell which allows DNA intake.

Once the electrical current discharged, the pores closed. The electroporation method is used for both stable and transient gene expression.

***Biolistic transformation***

The biolistic transformation is also known as a biolistic particle delivery system. In this method, a gene of interest coated with heavy metal ions is inserted into the target cell by mechanical force. Gene gun is a common name used for it. Molecules like DNA, RNA or protein can be inserted into a cell directly.

***Protoplast fusion:***

A cell without a cell wall or cell membrane is known as a protoplast. The protoplast fusion method is also used in the tissue culture methods in which two protoplasts of somatic cells are fused to get a hybrid protoplast of two different cells. It is commonly practiced in plant research to produce genetically altered plant species through their protoplast fusion.

***Microinjection:***

The microinjection method facilitates direct nuclear delivery of exogenous DNA. Using a fine needle, or injection, a DNA or gene is directly injected into the target cell nucleus without disrupting the endogenous pathway. The microinjection gene transfer technique is practiced to inject genes directly in oocytes, eggs and embryos.

**Chemical methods of gene transfer:**

Liposome mediated gene transfer, calcium phosphate mediated gene transfer, DEAE-Dextran mediated gene transfer and polyethylene glycol mediated gene transfer are common chemical methods used in transformation experiments.

Here the naked DNA is used to fuse the complex with a chemical agent (and therefore it is also known as naked-DNA mediated gene transfer). The chemical and DNA complex either interact with the cell wall or membrane or processed through endocytosis. Once it enters into the cell cytoplasm, the DNA is released from the chemical agent and incorporated into the genome.
In comparison with physical gene transfer techniques, the chemical method is slightly less effective, though.

***Liposome mediated gene transfer:***
Among all chemical methods, the liposome-mediated gene transfer or lipofection is most effective and used widely. The liposome is a phospholipid vesicle that inserts DNA once it interacts with the target cell.
It is a hydrophobic vesicle that surrounds the naked DNA and interacts with the cell wall or membrane. It inserts DNA into the cell cytoplasm. Although the method of making the liposome and incorporating DNA into it is tedious, time-consuming and labor-intensive.

***Calcium phosphate transfection:***
Yet another reliable chemical method of gene transfer is the calcium phosphate technique in which the DNA eluted in phosphate is mixed with the solution of calcium chloride and allows it to co-precipitate.
When mixed with the target cell population, some complex DNA and calcium phosphate precipitate when uptaken by the cells through the process of endocytosis and our DNA is inserted in the target cell.
The technique is simple, cost-effective, reliable than other methods and can transfect cells growing into the monolayer.
Note that it was the first method used to transfect the animal cells.

**Virus mediated gene transfer:**
The virus is the carrier of genetic material whose effort can help to transfer DNA in a target cell. Viruses are one of the most effective genes transfer vehicles.
Adenovirus, Adeno-associated virus, HIV, lentivirus and other retroviruses can be used for gene transfer. Although it can infect the host organism.

**Importance of gene transfer:**

Why are we doing gene transfer? The answer is to create a variation or to produce a new phenotype that is useful, beneficial and important for us. We have been using gene transfer techniques for so many years. In ancient times, crossing two different plants was common.
Inbreeding and crossbreeding were used to make various abiotic and biotic resistant plant species.

Even, the bacteria follow the natural mechanism of gene transfer to surviving in harsh conditions. Gene transfer was not new to use, perhaps but a substantial improvement in techniques was done in the mid 19s.

In the present time, the gene transfer techniques that we have are efficient enough and accurate. We are using gene transfer techniques to modify organisms' genome, especially the plant genome. To create various genetically modified plant species. Genetically modified plant species are created to fight against biotic and abiotic stress, increase the nutrient values, decreases the cost and to make it available for all. Furthermore, genetically modified organisms are constructed to produce proteins, therapeutics, drugs and other important biomolecules. The gene transfer technique is further practiced to cure disease and to treat patients.

Genes transfer techniques such as horizontal or vertical is performed to fulfill one global objective that is to create variations. The purpose of this is to make an organism adaptive in the present environment. Nonetheless, artificial gene transfer is performed to benefit us only. Prior ethical consent must be taken before performing any genetic engineering experiments.

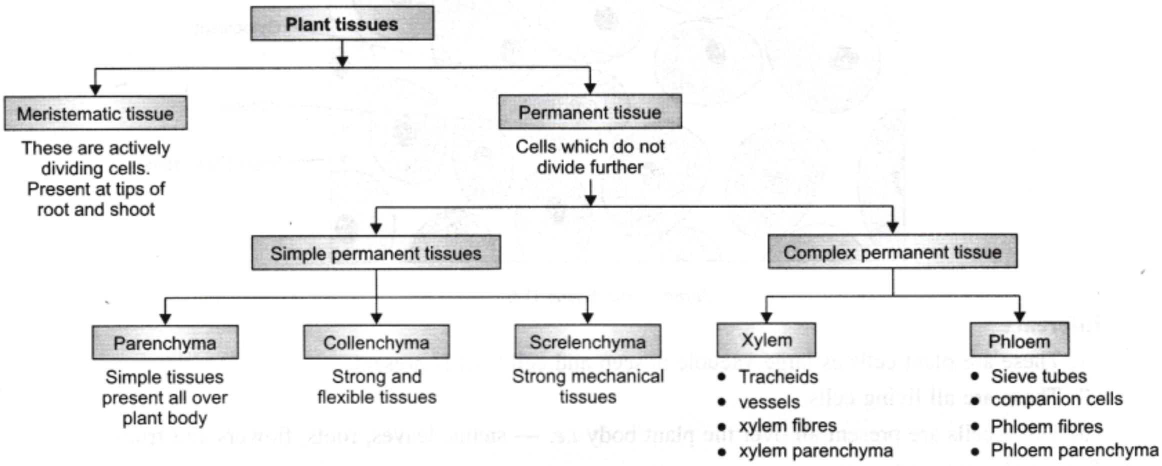
## .Unit 10.4 Cell Structure and Function

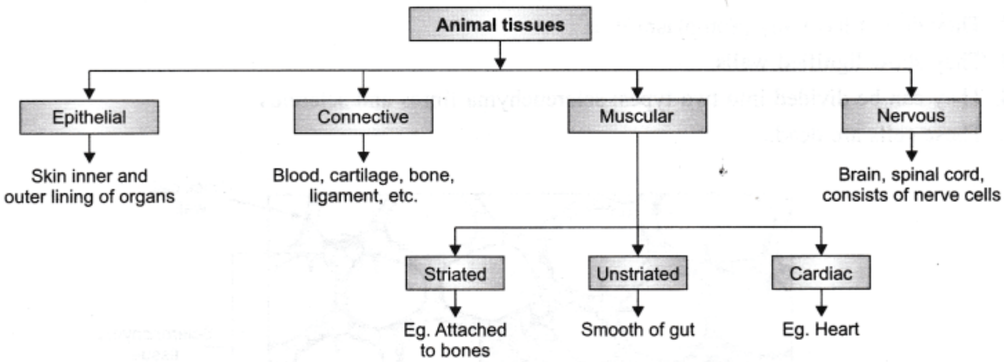
| Topic: Tissues and Organs in Plants and Animals | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmark** | **10.2.2.14** Assess how cells are specialized in different tissues and organs<br>**10.2.2.15** Research different cell parts, their functions and how they are specialized into different tissue and organs. |
| **Key question** | 1. Are tissues in plants and animals same?<br>2. What is the relationship between tissues and organs?<br>3. What are the organ systems of plant and animals<br>4. Why do animals have more organs than other |
| **Learning objectives** | • Identify the different types of plant and animal tissues.<br>• Explain the relationship between cells, tissues, organs and systems. |
| **Vocabulary** | Tissues, organs, |
| **Knowledge** | • Different types of plant and animal tissues<br>• Relationship between tissues and organs<br>• Structures and functions of tissues and organs in plants and animals. |
| **Skills** | • Identify and differentiate the different types of plant and animal tissues<br>• Analyse similarities and differences in plant and animal tissues and organs |
| **Attitudes and values** | • Value the importance of tissues and organs in plants and animals |
| **Teaching and Learning strategies** | 1. Research and model the plants and animal tissues<br>2. Investigate the relationship between cells, tissues and organs. |
| **Assessment** | 1. Select, research, and present findings on either a plant or animal tissue or organ |
| **Materials** | Handouts, textbooks, lab report sheets |

## Content Background

Multicellular organisms comprise millions of cells. These cells are grouped at different levels to enable the biological and chemical activities in the organism to occur harmoniously. A group of similar cells grouped together to perform a special function is called tissue.

Cells with similar structures and functions are massed together in tissues. Some plant and animal tissues are shown in the table below.




| Animal Tissue | Main function |
|---|---|
| **Epithelium** | Lines tubes such as the gut and covers surfaces such as skin |
| **Connective tissue** | Binds and strengthens other tissues, such as tendons |
| **Blood** | Transports substances around the body , and defends against disease |
| **Skeletal tissue** | Supports and protects softer tissues and allows |
| **Nervous tissue** | Sets up nerve impulses and transmits them around the body |
| **Muscle tissue** | Contracts to support and move the body |

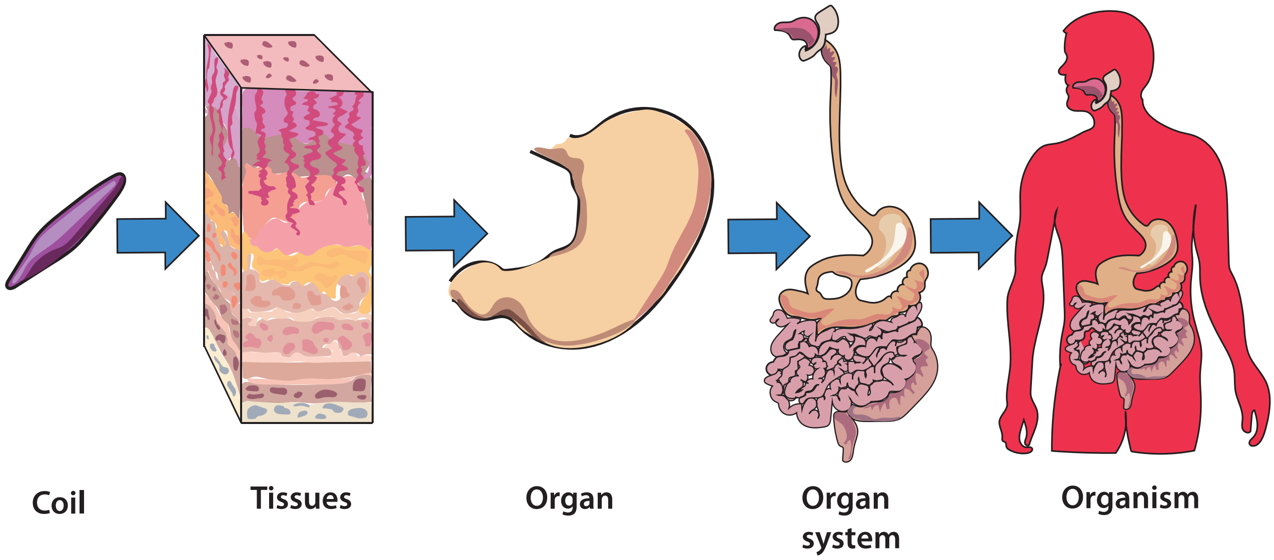
| Plant tissue | Main functions |
|---|---|
| Epidermis | Protects against water loss, and may be involved in absorption of water and ions |
| Mesophyll | Photosynthesis |
| Parenchyma | Fills spaces between other plant tissues and may be involved in storage, as in the potato tuber |
| Vascular tissue | Transports materials through the plant body |
| Strengthening tissue | Supports the plant. |

## Organs

An organ is a group of different tissues working together to enable the organ to perform its function. In animals, the heart for example, has different types of tissues working together ; it has muscle tissues to pump blood; blood vessels to supply the muscle cells with oxygen and nutrients for its action ; nervous tissue to regulate the heartbeat; and connective tissue to connect other tissues.

Similarly, in plants, the stem has different types of tissues working together; epithelial tissues are used for transport of water and mineral salts; phloem tissues are used to transport manufactured food substances.

### Levels of Organization



| Topic: Nervous System | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmark** | **10.2.2.15** Research different cell parts, their functions and how they are specialized into different tissue and organs.<br>**10.2.2.16** Evaluate the similarities and differences between the different systems of the body and the how these are related to each other. |
| **Key question** | 1. How does the nerve system function?<br>2. What is the difference between involuntary and voluntary reflexes?<br>3. What is the difference between central and peripheral nervous systems? |
| **Learning objectives** | • Describe the structure and role of the nervous system in animals.<br>• Describe and explain the structure and types of nerve cells and how they work in the nervous system.<br>• Differentiate between involuntary and voluntary reflexes.<br>• Explain what Central and peripheral nervous systems are and be able to differentiate one from the other. |
| **Vocabulary** | Central Nervous System (CNS), peripheral nervous system, receptors, involuntary, voluntary |
| **Knowledge** | • The structure and role of the nervous system in animals.<br>• The structure and types of nerve cells and how they work in the nervous system.<br>• Difference between involuntary and voluntary reflexes.<br>• Central and peripheral nervous systems and how they differentiate from each other. |
| **Skills** | • Analyse the structure and role of the nervous system in animals.<br>• Identify and analyse the structure of the different types of nerve cells and how they work.<br>• Differentiate between involuntary and voluntary reflexes.<br>• Differentiate between central and peripheral nervous systems |
| **Attitudes and values** | Appreciate science for its usefulness in improving quality of life |
| **Teaching and Learning strategies** | Teacher to prepare notes and handouts on the central nervous system, including nervous system in general. Also prepare charts/posters of human and other animal to compare. |
| **Assessment** | 1. Design a model of human nervous system and how it works |
| **Materials** | Paper or plastic models, rubber bands or similar, wood, lab report |

## Content Background

There are millions of cells and scores of different tissues and organs in the body of an animal such as a mammal. The cells and organs do not all work independently- their activities are coordinated, which means that they work together, carrying their various functions at certain times and at certain rates according to the needs of the body.

Coordination in mammals is achieved through two systems, each with its own particular role. The nervous system deals with the rapid but short-lasting responses, whereas the endocrine system brings about slower, longer lasting responses.

**Nervous System**

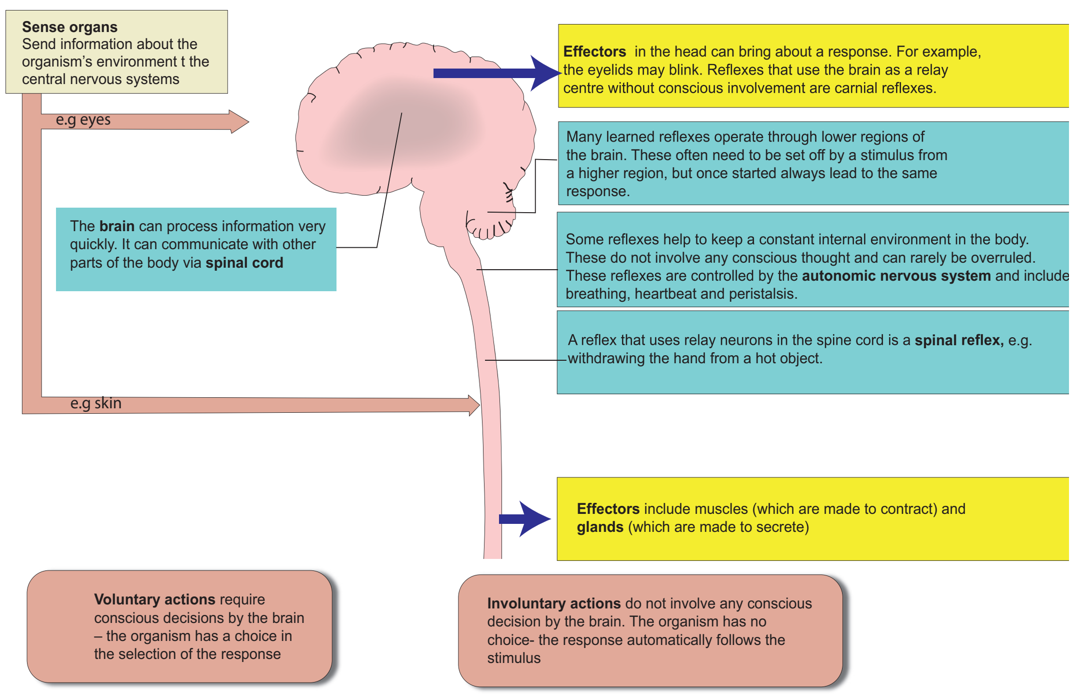
The nervous system is the network of body tissues that detect process and distribute information in the body using electrical and chemical transmissions. It is in two parts:

1) The central nervous system (CNS) which comprises the brain and spinal cord.
2) The peripheral nervous system (PNS), which consists of the cranial nerves from the brain (including the optic nerve), spinal nerves from the spinal cord and the sense organ that transmits sensation and motor information back and forth from the body to the central nervous system.

The sense organs receive stimuli and so they are appropriately called **receptors.** There are a wide range of receptors found in the sense organs of animals. There are receptors for light (photoreceptors) found in the retina in the eye. Olfactory receptors for smell in the nose, gustatory (taste) receptors in the tongue and pain receptors on the skin. There are also receptors that pick up stimuli from the internal environment, such as chemoreceptors that detect the concentration of carbon dioxide in the blood or hormones in the hypothalamus in the brain. They are responsible for informing the central nervous system of any changes in the surroundings, by transmitting sensory signals in the form of impulses. These nerve impulses are electrical in nature. The nerve impulse is transmitted by the nerves in a fraction of a section. For example, if someone touches your shoulder from behind, you will feel the touch almost instantaneously.

| Receptor | Stimulus detected | Location |
|---|---|---|
| Mechanoreceptors | Pain, pressure, gravity, touch | Skin, ear |
| Photoreceptors | Light | Rods and cones on the retina in the eye |
| Chemoreceptors | Chemicals | Taste buds, blood vessels, hypothalamus |
| Thermoreceptors | Temperature | Skin, hypothalamus |
| Electroreceptors | Electricity | Skin |

When the central nervous system receives the impulses, it processes the information and then sends the impulses to the muscles. The muscles will then carry out the necessary effects. For example if you see a poisonous snake in your path, you will flinch, jump back, scream or even look around for assistance. Again all these occur in a fraction of a second. Since the muscles act upon the instruction from the central nervous system and carry out their effects, they are called **effectors.** In short, nerve impulses are transmitted from the receptors to the central nervous system and then from there to the effectors. Hence, the brain, spinal cord and nerve tissues are the coordinators of both **involuntary** and **voluntary** actions in the body.




In simple terms:

**Stimulus** → **Sense organ** → **Central Nervous System** → **Effector** → **Response**

### Involuntary actions

Reflexes concerned with the 'housekeeping' tasks of the body, such as breathing, do not reach the conscious level of the brain. They are dealt with by the autonomic branch of the nervous system. Responses may be more complex than simple reflex arc. For example, the CNS may store information and then compare an incoming stimulus with a previous one. It chooses the correct response for this particular situation, and sends information out to the effectors to bring about the appropriate action. Each time a particular impulse passes along the same route, so that reflex actions become learned reflexes. Talking and cycling are examples of learned reflexes. Whether or not a reflex has been learned, it is an involuntary action- a particular stimulus always leads to the same response.

**Voluntary Actions**

During evolution, the front of the spinal cord became highly developed to form the brain. The advanced development of the brain, particularly those parts that deal with learning, sets mammals ( and especially humans) apart from 'lower animals. The brain is involved in the voluntary actions, in which a conscious choice is made about the response to a particular stimulus.

**Nerve Tissue**

The nervous tissue is made up of specialized cells called **nerve cells.** Although the size and shape of neurons differ in different parts of the body, their general structure is similar. Each neurone consists of a **cell body** with a nucleus and cytoplasmic process called nerve fibres that transmit impulses. There are three types of neurones:

- **Sensory neurones** or receptor neurones which transmit impulses from the sense organs or receptors to the central nervous system. For example, the photoreceptors in the eye might receive the stimulus from the environment that the light has increased. They then send this information to the brain.
- **Motor neurones,** which transmit impulses from the central nervous system to the effector cells. The effector cells then carry out the response to the stimulus detected by the original sensory neuron. So if the message sent by the photoreceptors informs the brain that there is too much light hitting the retina, the motor neuron then sends the message to the muscles around the iris to constrict the pupil, so that less light enters the eye.
- **Relay neurones (**also known as association, connector, multipolar or interneurons) are found in the nervous system and communicating with the rest of the body. For example, they communicate between sensory neurones and motor neurones as well as between themselves.

**Nerve impulses**

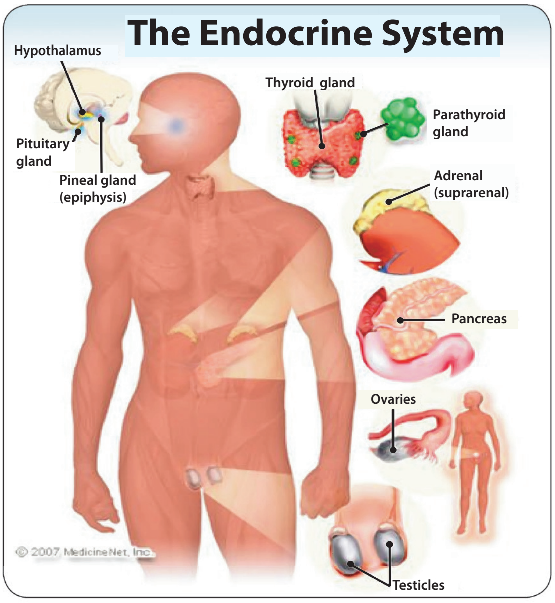
Messages pass along neurons in the form of **electrical impulses** called **action potentials** which travel very quickly from one end of a nerve cell to the other. In a living mammal the impulses always travel along a neurone in a certain direction**.** They are then passes on to another neurone, to a muscle cell or to a gland cell. The end of the neurone is separated from the next cell by a tiny gap, visible under a microscope, and the impulse can only cross this gap in one direction. This gap , called a synapse, acts like a valve.

## Topic: Endocrine System

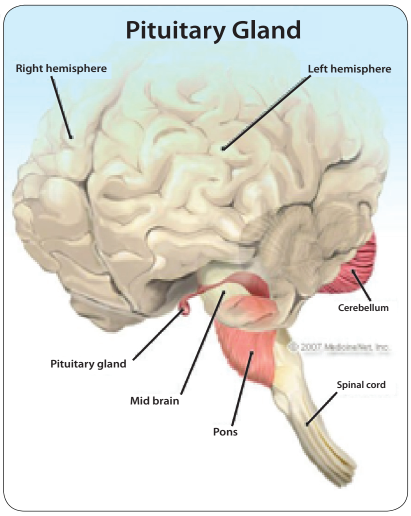
| | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmark** | **10.2.2.14** Assess how cells are specialized in different tissues and organs.<br>10.2.2.16 Evaluate the similarities and differences between the different systems of the body and the how these are related to each other. |
| **Key question** | 1. What are the roles and functions of hormones and glands in our body? |
| **Learning objectives** | By the end of the topic, students can:<br>• Identify the major types of glands in a human body<br>• Describe the roles and functions of the major glands in a human body<br>• Explain the roles of hormones in a human body |
| **Vocabulary** | Hypothalamus, pituitary gland, hormone, endocrine system, thyroid gland, reproductive gland, pancreas. |
| **Knowledge** | • Roles and functions of major glands in our body<br>• Roles and function of hormones in our body<br>• Diseases of the endocrine systems |
| **Skills** | • Analyse roles and functions of endocrine system.<br>• Evaluate the health issues related to roles and function of the endocrine system. |
| **Attitudes and values** | • Care and respect for our endocrine system |
| **Teaching and Learning strategies** | Teacher to prepare notes, including diagrams of the endocrine system. |
| **Assessment** | 1. Carry out community research on diseases related to endocrine system failure and effects on individuals and present findings to class. |
| **Materials** | Library books, charts/diagrams, lab report sheets with research guidelines |

## Content Background

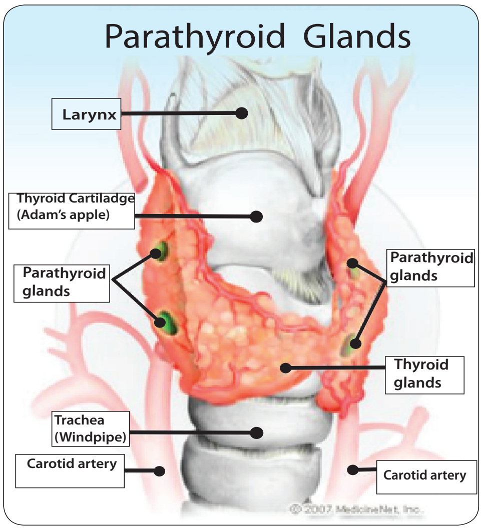
The endocrine system is the collection of glands that produce hormones that produce and secrete hormones, chemical substances produced in the body that regulate the activity of cells or organs. These hormones regulate metabolism, growth and development, tissue function, sexual function, reproduction, sleep and mood, among others.




The word endocrine is derived from the Greek words "endo," meaning within, and "crinis," meaning to secrete. In general, a gland selects and removes materials from the blood, processes them and secretes the finished chemical product for use somewhere in the body. The endocrine system affects almost every organ and cell in the body.



Hormones are chemical messengers created by the body. They transfer information from one set of cells to another to coordinate the functions of different parts of the body. The major glands of the endocrine system are the hypothalamus, pituitary gland, thyroid gland, parathyroid glands, adrenal glands, pancreas, ovaries (in female) and testicles (in males).




Although the hormones circulate throughout the body, each type of hormone is targeted toward certain organs and tissues. The endocrine system gets some help from organs such as the kidney, liver, heart and gonads, which have secondary endocrine functions. The kidney, for example, secretes hormones such as erythropoietin and renin.

The thyroid also secretes a range of hormones that affect the whole body. "Thyroid hormones impact a host of vital body functions, including heart rate, skin maintenance, growth, temperature regulation, fertility and digestion

| **Part** | **Function** |
|---|---|
| **Hypothalamus** | The hypothalamus is located in the lower central part of the brain. This part of the brain is important in regulation of satiety, metabolism, and body temperature. In addition, it secretes hormones that stimulate or suppress the release of hormones in the pituitary gland. Many of these hormones are releasing hormones, which are secreted into an artery (the *hypophyseal* portal system) that carries them directly to the pituitary gland. In the pituitary gland, these releasing hormones signal secretion of stimulating hormones. The hypothalamus also secretes a hormone called *somatostatin*, which causes the pituitary gland to stop the release of growth hormone. |

| | |
|---|---|
| **Pituitary Gland** | The pituitary gland is located at the base of the brain beneath the hypothalamus and is no larger than a pea. It is often considered the most important part of the endocrine system because it produces hormones that control many functions of other endocrine glands. When the pituitary gland does not produce one or more of its hormones or not enough of them, it is called hypopituitarism.<br>The pituitary gland is divided into two parts: the anterior lobe and the posterior lobe. The anterior lobe produces the following hormones, which are regulated by the hypothalamus:<br>• Growth hormone: Stimulates growth of bone and tissue (Growth hormone deficiency results in growth failure. Growth hormone deficiency in adults results in problems in maintaining proper amounts of body fat and muscle and bone mass. It is also involved in emotional well-being.)<br>• Thyroid-stimulating hormone (TSH): Stimulates the thyroid gland to produce thyroid hormones (A lack of thyroid hormones either because of a defect in the pituitary or the thyroid itself is called hypothyroidism.)<br>• Adrenocorticotropin hormone (ACTH): Stimulates the adrenal gland to produce several related steroid hormones<br>• Luteinizing hormone (LH) and follicle-stimulating hormone (FSH): Hormones that control sexual function and production of the sex steroids, estrogen and progesterone in females or testosterone in males<br>• Prolactin: Hormone that stimulates milk production in females<br>The posterior lobe produces the following hormones, which are not regulated by the hypothalamus:<br>•Antidiuretic hormone (vasopressin): Controls water loss by the kidneys<br>•Oxytocin: Contracts the uterus during childbirth and stimulates milk production<br>The hormones secreted by the posterior pituitary are actually produced in the brain and carried to the pituitary gland through nerves. They are stored in the pituitary gland. |
| **Thyroid Gland** | The thyroid gland is located in the lower front part of the neck. It produces thyroid hormones that regulate the body's metabolism. It also plays a role in bone growth and development of the brain and nervous system in children. The pituitary gland controls the release of thyroid hormones. Thyroid hormones also help maintain normal blood pressure, heart rate, digestion, muscle tone, and reproductive functions. |
| **Parathyroid Glands** | The parathyroid glands are two pairs of small glands embedded in the surface of the thyroid gland, one pair on each side. They release parathyroid hormone, which plays a role in regulating calcium levels in the blood and bone metabolism. |
| **Adrenal Glands** | The two adrenal glands are triangular-shaped glands located on top of each kidney. The adrenal glands are made up of two parts. The outer part is called the adrenal cortex, and the inner part is called the adrenal medulla. The outer part produces hormones called corticosteroids, which regulate the body's metabolism, the balance of salt and water in the body, the immune system, and sexual function. The inner part, or adrenal medulla, produces hormones called catecholamines (for example, adrenaline). These hormones help the body cope with physical and emotional stress by increasing the heart rate and blood pressure. |
| **Reproductive Glands** | The reproductive glands are the main source of sex hormones. In males, the testes, located in the scrotum, secrete hormones called androgens; the most important of which is testosterone. These hormones affect many male characteristics (for example, sexual development, growth of facial hair and pubic hair) as well as sperm production. In females, the ovaries, located on both sides of the uterus, produce estrogen and progesterone as well as eggs. These hormones control the development of female characteristics (for example, breast growth), and they are also involved in reproductive functions (for example, menstruation, pregnancy). |
| **Pancreas** | The pancreas is an elongated organ located toward the back of the abdomen behind the stomach. The pancreas has digestive and hormonal functions. One part of the pancreas, the exocrine pancreas, secretes digestive enzymes. The other part of the pancreas, the endocrine pancreas, secretes hormones called insulin and glucagon. These hormones regulate the level of glucose (sugar) in the blood. |

**Diseases of the endocrine system**

Hormone levels that are too high or too low indicate a problem with the endocrine system. Hormone diseases also occur if your body does not respond to hormones in the appropriate ways. Stress, infection and changes in the blood's fluid and electrolyte balance can also influence hormone levels, according to the National Institutes of Health.

A common endocrine disease is diabetes, a condition in which the body does not properly process glucose, a simple sugar. This is due to the lack of insulin or, if the body is producing insulin, because the body is not working effectively. Diabetes can be linked to obesity, diet and family history. To diagnose diabetes, do an oral glucose tolerance test with fasting.

It is also important to understand the patient's health history as well as the family history. Infections and medications such as blood thinners can also cause adrenal deficiencies.

Diabetes is treated with pills or insulin injections. Managing other endocrine disorders typically involves stabilising hormone levels with medication or, if a tumor is causing an overproduction of a hormone, by removing the tumor. Treating endocrine disorders takes a very careful and personalised approach, as adjusting the levels of one hormone can impact the balance of other hormones.

Hormone imbalances can have a significant impact on the reproductive system, particularly in women.

Another disorder, hypothyroidism, a parathyroid disease, occurs when the thyroid gland does not produce enough thyroid hormone to meet the body's needs. Insufficient thyroid hormone can cause many of the body's functions to slow or shut down completely. It has an easy treatment, though. Thyroid cancer begins in the thyroid gland and starts when the cells in the thyroid begin to change, grow uncontrollably and eventually form a tumor. Tumors — both benign and cancerous — can also disrupt the functions of the endocrine system.

Hypoglycemia, also called low blood glucose or low blood sugar, occurs when blood glucose drops below normal levels. This typically happens as a result of treatment for diabetes when too much insulin is taken. The condition can occur in people not undergoing treatment for diabetes, such an occurrence is fairly rare.

## Unit 10.5: Interactions and Relationships in the Environment

| Topic: Cycles in the Biosphere | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmark** | **10.2.2.23** Examine the components and the functions of a variety of macromolecules active in biological systems.<br>**10.2.2.25** Investigate water cycle in the ecosystem.<br>**10.2.2.26** Investigate carbon cycle in the ecosystem. |
| **Key questions** | 1. Why are cycles in the biosphere important?<br>2. How does the water cycle through the biosphere?<br>3. What are the types of biogeochemical cycles? |
| **Learning objectives** | • identify the steps of the carbon cycle and explain its significance to global ecosystems.<br>• Identify the steps of the nitrogen cycle and explain its significance to global ecosystems.<br>• Identify the steps of the water cycle and explain its significance to global ecosystems. |
| **Vocabulary** | evaporation, transpiration, sublimation, condensation, advection, precipitation, infiltration, runoff, respiration, combustion, decay, carbon source, photosynthesis, carbon sinks, nitrogen fixation, nitrification, assimilation, denitrification, ammonification |
| **Knowledge** | • The process of carbon cycle and its significance to life and other biological systems<br>• The process of water cycle and its significance to life and other biological systems<br>• The process of nitrogen cycle and its significance to life and other biological systems |
| **Skills** | • Analyse relationships between water cycle and the ecosystem<br>• Compare nitrogen, carbon, and water cycles in terms of their roles and benefits to life on earth |
| **Attitudes and values** | Appreciate the value of water, nitrogen and carbon cycles in our life. |
| **Teaching and Learning strategies** | Teacher to prepare notes and handouts on the three types of cycles. Teacher can also find guidelines, materials etc. to assist students make models of these cycles |
| **Assessment** | 1. Select one of these; carbon cycle, nitrogen cycle or water cycle and make a model of this and present to class. |
| **Materials** | several sheets of blank paper<br>Colored pencils<br>Computer with internet access |

### Content Background

The Sun keeps supplying energy to food chains. However, the supply of chemical elements to living organisms is limited, and these elements must be recycled. The nutrient elements are cycled between simple forms in the non-living (abiotic) environment and more complex forms in the bodies of living organisms (the biotic component of an ecosystem). Living organisms require carbon-containing compounds as:

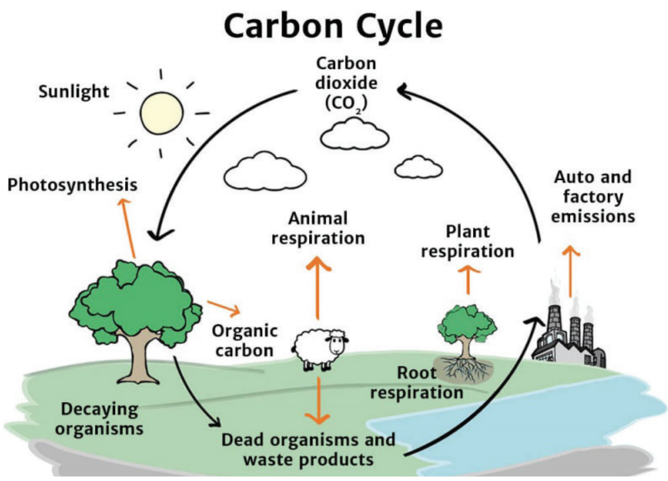
- A source of energy, released when carbon containing compounds are oxidised during respiration (particularly carbohydrates and fats).
- Raw materials for the growth of cells (particularly fats and proteins).

**The Carbon cycle**
Carbon is the basic building block of all **organic** materials, and therefore, of living organisms. Most of the carbon on earth can be found in the crust. Other reservoirs of carbon include the oceans and atmosphere.

Carbon moves from one reservoir to another by these processes:

- **Combustion**: Burning of wood and fossil fuels by factory and auto emissions transfers carbon to the atmosphere as carbon dioxide.
- **Photosynthesis**: Carbon dioxide is taken up by plants during photosynthesis and is converted into energy rich organic molecules, such as glucose, which contains carbon.
- **Metabolism**: Autotrophs convert carbon into *organic* molecules like fats, carbohydrates and proteins, which animals can eat.
- **Cellular respiration**: Animals eat plants for food, taking up the organic carbon (carbohydrates). Plants and animals break down these organic molecules during the process of cellular respiration and release energy, water and carbon dioxide. Carbon dioxide is returned to the atmosphere during gaseous exchange.
- **Precipitate**: Carbon dioxide in the atmosphere can also **precipitate** as carbonate in ocean sediments.
- **Decay**: Carbon dioxide gas is also released into the atmosphere during the decay of all organisms.

**Photosynthesis** and **gaseous exchange** are the main carbon cycling processes involving living organisms. The Figure below depicts the carbon cycle.



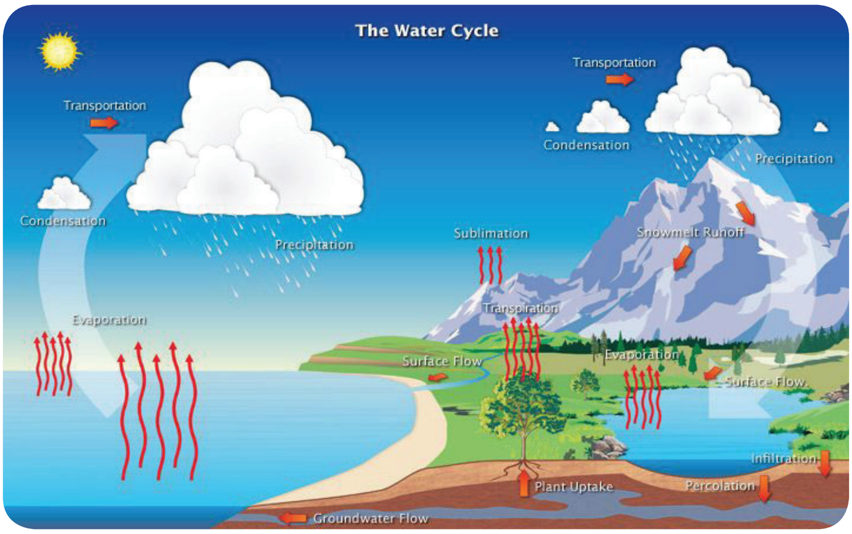

## The Water Cycle

Over two thirds of the Earth's surface is covered by water. It forms an important component of most life forms, with up to 70% of plants and animals being composed of water. Vast quantities of water cycle through Earth's atmosphere, oceans, land and biosphere. This cycling of water is called the **water** or **hydrological** cycle. The cycling of water is important in determining our weather and climate, supports plant growth and makes life possible.

- **Evaporation**: Most water evaporates from the oceans, where water is found in highest abundance. However some evaporation also occurs from lakes, rivers, streams and following rain.
- **Transpiration**: Is the water loss from the surface area (particularly the stomata) of plants. Transpiration accounts for a massive 50% of land-based evaporation, and 10%of total evaporation.
- **Evapotranspiration**: The processes of evaporation and transpiration are often collectively referred to as evapotranspiration.
- **Condensation**: The process by which water vapour is converted back into liquid is called condensation. You may have observed a similar process occurring when dew drops form on a blade of grass or on cold glass. Water in the atmosphere condenses to form clouds.
- **Precipitation**: Water returns to Earth through precipitation in the form of rain, sleet, snow or ice (hail). When rain occurs due to precipitation, most of it runs off into lakes and rivers while a significant portion of it sinks into the ground.

- **Infiltration**: The process through which water sinks into the ground is known as infiltration and is determined by the soil or rock type through which water moves. During the process of sinking into the Earth's surface, water is filtered and purified. Depending on the soil type and the depth to which the water has sunk, the ground water becomes increasingly purified: the deeper the water, the cleaner it becomes.
- **Melting and freezing**: Some water freezes and is 'locked up' in ice, such as in glaciers and ice sheets. Similarly, water sometimes melts and is returned to oceans and seas.

The processes involved in the water cycle are shown in the diagram below



| Topic: Earth's Ecosystem | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmark** | **10.2.2.23** Examine the components and the functions of a variety of macromolecules active in biological systems.<br>**10.2.2.24** Explore different types of biodiversity in an ecosystem. |
| **Key questions** | 1. What is the ecosystem?<br>2. What are the different types of ecosystems?<br>3. Which ecosystem do we live in?<br>4. What is the structure of the ecosystem?<br>5. Which is the largest ecosystem in the world?<br>6. What is the major function of an ecosystem?<br>7. What makes a good ecosystem? |
| **Learning objectives** | By the end of the topic, students can:<br>• Demonstrate understanding of the earth's ecosystems.<br>• Explain the causes and effects of human impact on the different types of ecosystems.<br>• Describe the different types of earth's ecosystems. |
| **Vocabulary** | Aquatic, terrestrial, biodiversity, macromolecules, biotic factors, abiotic factors |
| **Knowledge** | • Types of earth's ecosystems.<br>• Structure and function of an ecosystem.<br>• Types of Aquatic and terrestrial ecosystems.<br>• Characteristics of typical aquatic and terrestrial ecosystems. |
| **Skills** | • Compare the different types of earth's ecosystems.<br>• Analyse the components and functions of biodiversity in an ecosystem.<br>• Evaluate the causes and effects of human impact on the earth's ecosystems. |
| **Attitudes and values** | • Show love and respect for forms of life on earth.<br>• Appreciate the interrelationships that all components of an ecosystem have on each other. |
| **Teaching and Learning strategies** | Teacher to prepare notes on the different types of ecosystems on earth for students. It would be a great way of learning if students can make models of a specific ecosystem, including structure and functions of the components of the ecosystem. |
| **Assessment** | 1. Make a model of a specific ecosystem of their choice. |
| **Materials** | Materials that can be used to construct models of ecosystem, library, video |

## Content Background

Ecosystem Earth

An ecosystem consists of communities of interacting species and the physical environment on which they depend. Although it is well accepted that Earth consists of many different ecosystems, human societies much less readily recognize that Earth itself is an ecosystem, dependent on interacting species and consisting of finite resources. As the human population has grown and increasingly dominated available resources, "ecosystem Earth" has begun to show increasing signs of stress. Loss of biodiversity, environmental degradation, and conflict over resources among the dominant species are typical signs that a biological system is nearing a state change, which could range from collapse of the dominant species, to development of alternative biological communities, to collapse of the entire system. In this special issue, we identify our impacts on ecosystem Earth, seek to understand the barriers to change, and explore potential solutions. Decades of research on ecosystem dynamics can help to guide our thinking about a sustainable future. Bottom-up reductions in human population growth and resource consumption, changes to how we think about our place in the system, and a willingness to prioritize persistence of the other species within our biological community will lead to a healthier planetary ecosystem. It is essential that humanity begins to better appreciate our role as just one part of a large and interdependent biological community. Our ability to dominate the planet's resources makes us directly responsible for determining the future of the ecosystem on which we, and all other forms of life, depend.

What is an Ecosystem?

The ecosystem is the structural and functional unit of ecology where the living organisms interact with each other and the surrounding environment. In other words, an ecosystem is a chain of interaction between organisms and their environment. The term "Ecosystem" was first coined by A.G.Tansley, an English botanist, in 1935.

Types of Ecosystem

An ecosystem can be as small as an oasis in a desert, or as big as an ocean, spanning thousands of miles. There are two types of ecosystem:

- Terrestrial Ecosystem
- Aquatic Ecosystem

Terrestrial Ecosystems

Terrestrial ecosystems are exclusively land-based ecosystems. There are different types of terrestrial ecosystems distributed around various geological zones. They are as follows:

1. Forest Ecosystems
2. Grassland Ecosystems
3. Tundra Ecosystems
4. Desert Ecosystem

*Forest Ecosystem*

A forest ecosystem consists of several plants, animals and microorganisms that live in coordination with the abiotic factors of the environment. Forests help in maintaining the temperature of the earth and are the major carbon sink.

*Grassland Ecosystem*

In a grassland ecosystem, the vegetation is dominated by grasses and herbs. Temperate grasslands, savanna grasslands are some of the examples of grassland ecosystems.

*Tundra Ecosystem*

Tundra ecosystems are devoid of trees and are found in cold climates or where rainfall is scarce. These are covered with snow for most of the year. The ecosystem in the Arctic or mountain tops is tundra type.

*Desert Ecosystem*

Deserts are found throughout the world. These are regions with very little rainfall. The days are hot and the nights are cold.

**Aquatic Ecosystem**

Aquatic ecosystems are ecosystems present in a body of water. These can be further divided into two types, namely:

1. Freshwater Ecosystem
2. Marine Ecosystem

*Freshwater Ecosystem*

The freshwater ecosystem is an aquatic ecosystem that includes lakes, ponds, rivers, streams and wetlands. These have no salt content in contrast with the marine ecosystem.

*Marine Ecosystem*

The marine ecosystem includes seas and oceans. These have a more substantial salt content and greater biodiversity in comparison to the freshwater ecosystem.

**Structure of the Ecosystem**

The structure of an ecosystem is characterised by the organisation of both biotic and abiotic components. This includes the distribution of energy in **our environment**. It also includes the climatic conditions prevailing in that particular environment.
The structure of an ecosystem can be split into two main components, namely:

- Biotic Components
- Abiotic Components

The biotic and abiotic components are interrelated in an ecosystem. It is an open system where the energy and components can flow throughout the boundaries.

**Biotic Components**

Biotic components refer to all life in an ecosystem. Based on nutrition, biotic components can be categorised into autotrophs, heterotrophs and saprotrophs (or decomposers).

- **Producers** include all autotrophs such as plants. They are called autotrophs as they can produce food through the process of photosynthesis. Consequently, all other organisms higher up on the food chain rely on producers for food.
- **Consumers** or heterotrophs are organisms that depend on other organisms for food. Consumers are further classified into primary consumers, secondary consumers and tertiary consumers.
    - ***Primary consumers*** are always herbivores that they rely on producers for food.
    - ***Secondary consumers*** depend on primary consumers for energy. They can either be a carnivore or an omnivore.
    - ***Tertiary consumers*** are organisms that depend on secondary consumers for food. Tertiary consumers can also be an omnivore.
    - ***Quaternary consumers*** are present in some food chains. These organisms prey on tertiary consumers for energy. Furthermore, they are usually at the top of a food chain as they have no natural predators.
- **Decomposers** include saprophytes such as fungi and bacteria. They directly thrive on the dead and decaying organic matter. Decomposers are essential for the ecosystem as they help in recycling nutrients to be reused by plants.

**Abiotic Components**

Abiotic components are the non-living component of an ecosystem. It includes air, water, soil, minerals, sunlight, temperature, nutrients, wind, altitude, turbidity, etc.

**Functions of Ecosystem**

The functions of the ecosystem are as follows:

1. It regulates the essential ecological processes, supports life systems and renders stability.
2. It is also responsible for the cycling of nutrients between biotic and abiotic components.
3. It maintains a balance among the various trophic levels in the ecosystem.
4. It cycles the minerals through the biosphere.
5. The abiotic components help in the synthesis of organic components that involves the exchange of energy.

**Important Ecological Concepts**

1. Food Chain

The sun is the ultimate source of energy on earth. It provides the energy required for all plant life. The plants utilise this energy for the process of photosynthesis, which is used to synthesise their food.

During this biological process, light energy is converted into chemical energy and is passed on through successive levels. The flow of energy from a producer, to a consumer and eventually, to an apex predator or a detritivore is called the food chain.

Dead and decaying matter, along with organic debris, is broken down into its constituents by scavengers. The reducers then absorb these constituents. After gaining the energy, the reducers liberate molecules to the environment, which can be utilised again by the producers.

A classic example of a food chain in an ecosystem

2. Ecological Pyramids

An ecological pyramid is the graphical representation of the number, energy, and biomass of the successive trophic levels of an ecosystem. Charles Elton was the first ecologist to describe the ecological pyramid and its principals in 1927.

The biomass, number, and energy of organisms ranging from the producer level to the consumer level are represented in the form of a pyramid; hence, it is known as the ecological pyramid.

The base of the ecological pyramid comprises the producers, followed by primary and secondary consumers. The tertiary consumers hold the apex. In some food chains, the quaternary consumers are at the very apex of the food chain.

The producers generally outnumber the primary consumers and similarly, the primary consumers outnumber the secondary consumers. And lastly, apex predators also follow the same trend as the other consumers; wherein, their numbers are considerably lower than the secondary consumers.

For example, Grasshoppers feed on crops such as cotton and wheat, which are plentiful. These grasshoppers are then preyed upon by common mice, which are comparatively less in number. The mice are preyed upon by snakes such as cobras. Snakes are ultimately preyed on by apex predators such as the brown snake eagle.

In essence:

**Grasshopper →Mice→ Cobra → Brown Snake Eagle**

3. Food Web

Food web is a network of interconnected food chains. It comprises all the food chains within a single ecosystem. It helps in understanding that plants lay the foundation of all the food chains. In a marine environment, phytoplankton forms the primary producer.

| Topic: Biodiversity and Succession | |
|---|---|
| **Content standard** | Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment. |
| **Benchmarks** | **10.2.2.23** Examine the components and the functions of a variety of macromolecules active in biological systems.<br>**10.2**.2.24 Explore different types of biodiversity in an ecosystem. |
| **Key question** | 1. What is biodiversity?<br>2. What is succession? |
| **Learning objectives** | By the end of the topic, students can:<br>• Demonstrate their understanding of how different life forms (plants) can grow and regrow in different types of environments.<br>• Explain the relationship between biodiversity and succession.<br>• Describe the historical events such as natural and man-made hazards that have caused plant life to struggle overtime in terms of regeneration. |
| **Vocabulary** | Biomass, over-exploitation, succession, biodiversity, pioneer species, intermediate species, climax community, primary succession, ecological succession, secondary succession |
| **Knowledge** | • Causes and effects of natural and man-made causes and effects on plants in terms of natural succession<br>• Relationship between biodiversity and succession<br>• Growth and regrowth of plants in different types of environments.<br>• Processes of succession (primary and secondary successions) |
| **Skills** | • Evaluate a variety of ecological successions or conditions in which plant species can regenerate.<br>• Analyse a variety of ecological successions<br>• Identify patterns in ecological successions |
| **Attitudes and values** | • Beware of the causes and effects on the lives of plants and animals in terms of human or natural disasters. |
| **Teaching and Learning strategies** | Teacher to do some fact findings around the community to identify locations where destructions have occurred and affected plant and animal life. Set up project for students to study and monitor growth and regeneration of life in that location for a period of 1-2 years and report findings of the progress of growth and regenation. |
| **Assessment** | 1. Research recent natural or man-made events that have resulted in the destruction of plant and animal life and present findings on how these organisms are able to regenerate. |
| **Materials** | Library books, social media, destruction sites around the community, pictures of ecological succession (process) |

## Content Background

Humankind has dramatically transformed much of the Earth's surface and its natural ecosystems. This process is not new. It has been on-going for thousands of years, however, it has accelerated sharply over the last two centuries, and especially in the last several decades. Today, the lost and degradation of natural habitats can be likened to a war of attrition. Many natural ecosystems are being progressively razed, bulldozed, and felled by axes or chainsaws, until only small scraps of their original extent survive. Forests have been hit especially hard: the global area of forests has been reduced by roughly half over the past two centuries. Twenty-five nations of the world have lost virtually all of their forest cover, and another 29 more have lost more than nine-tenth of their forests (MEA 2005)

Tropical forests are disappearing at up to 130 000 km² a year – roughly 50 football fields a minute. Other ecosystems are less imperilled (put at risk), and a few are somewhat following past centuries of over-exploitation. This is just an overview of contemporary habitat loss. Other ways that ecosystems are being threatened include:  over-hunting, habitat fragmentation, and climate change.

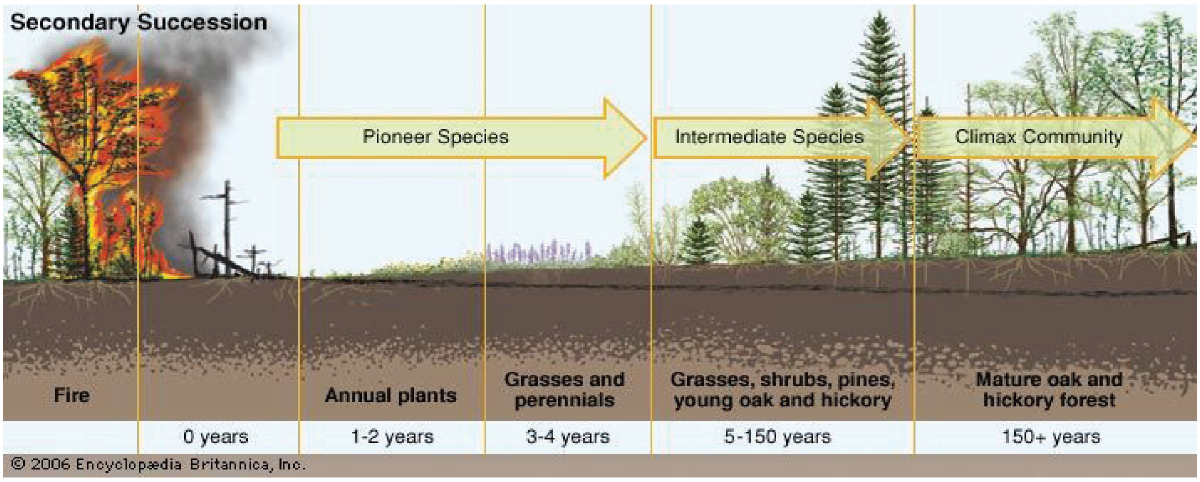
Students are expected to evaluate patterns of destruction geographically in their local contexts (land and sea/water ecosystems) as well as explore similar examples on a national and global scale. They make comparisons and draw conclusions amongst different biomass and ecosystems. They also consider some of the ultimate and proximate factors that drive habitat loss, and how they are changing today.

## Succession

Succession is a process in which communities of plant and animal species are replaced in a particular area over time by a series of different and usually more complex communities as the available soil becomes more plentiful.

Each species modifies the habitat in which it lives. It may provide food for other species, it may provide a living space for others, or it may make the environment unsuitable for previously successful species.

Here is an example where a forest area was destroyed by bush fire and the regeneration of the forest over the years through a succession process.




Ecological succession is the process that describes how the structure of a biological community (that is, an interacting group of various species in a desert, forest, grassland, marine environment, and so on) changes over time. Species that arrive first in a newly created environment (such as an island rising out of the sea) are called pioneer species, and they, through their interactions with one another, build a rather simple initial biological community. The structure of this community becomes more complex as new species arrive on the scene.

At every stage there are certain species that have evolved life histories to exploit the particular conditions of the community.

Primary succession is ecological succession that begins in essentially lifeless areas, such as regions in which there is no soil or where the soil is incapable of sustaining life (because of recent lava flows, newly formed sand dunes, or rocks left from a retreating glacier). The first species to arrive are fast-growing “weedy species,” such as lichens or small annual plants, which create the first layers of soil as they decompose. These plants also provide habitats for small animals and other forms of life. These plants are replaced by grasses and shrubs, which shade out the first colonizers and alter the soil further, before large trees and more shade-tolerant species replace the community of sun-loving grasses and shrubs. Each community may support different collections of animal species.

Secondary succession occurs in areas where a biological community has already existed but some or all of that community has been removed by small-scale disturbances that did not eliminate all life and nutrients from the environment. Although fire, flooding, and other disturbances may drive out many plants and animals and set back the biological community to an earlier stage, the community does not “start from scratch” as it would during primary succession because the soil, which contains many nutrients provided by the former biological community, remains.

## Unit 10.6: Matter and Energy

This unit provides students with the opportunity to examine the interactions among elements as they form compounds through chemical reactions. Students become familiar with the formulas and naming of binary compounds, and investigate the Law of Conservation of Mass. The recognition that mass is conserved in chemical reactions allows students to balance equations with both words and symbols, and classify them by type. The principles of acid-base chemistry are studied and extended to large-scale environmental interactions. Students investigate the use of chemistry in biological, industrial, and domestic settings, recognizing that chemical use is common in modern society.

This cluster builds on the particle theory of matter learned in previous grades. Students become familiar with the basic constituents of matter by learning about the historical development of the atomic model and the periodic table. Various investigations of the properties of elements and compounds will acquaint students with chemical symbols and families, as well as with natural phenomena and everyday technologies that demonstrate chemical change.

| Topic 1: Solubility | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.4** Connect local technologies, including the utilization and preservation of materials, to either causing or controlling changes in matter. |
| **Key question** | 1. How do salts form?<br>2. What are some of the factors that speed up the rate of dissolving a substance?<br>3. What is solubility? |
| **Learning objectives** | By the end of this topic, students can:<br>• Identify and explain the factors that affect the rate of solubility of substances.<br>• Explain the process of extracting salt. |
| **Vocabulary** | • Soluble, insoluble, solvent, solute, evaporation, decanting, filtering |
| **Knowledge** | • Heat and temperature are factors that affect the rate of solubility of a substance. |
| **Skills** | • Extracting salt from sea water.<br>• Evaluate the processes of evaporation, decanting and filteration<br>• Demonstrate the process of extracting salt from seawater. |
| **Attitudes and values** | Value the factors that affect the solubility of a substance<br>Appreciate the impotance of filteration, evaporation and decanting in our life. |
| **Teaching and Learning strategies** | Provide handouts, conduct experiment of extracting salt crystals from salt water solution. |
| **Assessment** | 1. How can a substance's surface are be increased to dissolve it faster in a liquid? (an experiment can be conducted to prove students answers) |
| **Materials** | Salt crystals, salt solution (Sodium chloride), water, spoon, other soluble and insoluble substances. |

## Content Background

### Solubility

Many raw materials are mixtures of soluble and insoluble substances which can be separated using different solubilities. In order to extract the maximum amount of a soluble substance from a solid mixture, the mixture is usually crushed or ground into small pieces. Chopping or grinding and crushing a solid increases the surface area with which the solvent makes contact. This allows the soluble substance to dissolve more quickly. For example, a cup of tea is made by adding boiling water to chopped tea leaves. Chemicals in the tea leaves dissolve in the water and the remainder of the leavers settle to the bottom of the cup.

The liquid that a substance is dissolved in is called the *solvent*. The substances that dissolve in the liquid are called the *solutes*. In the example of tea, water is the solvent, and the substances that give tea its colour and taste are the solutes. Water is a very common solvent, but many other liquids are also used as solvents. Other solvents include alcohol and petrol.

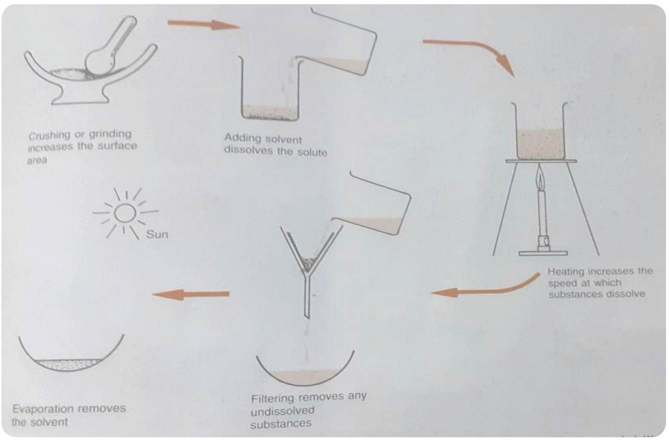
Hot water increases the speed at which the substances dissolve. If tea is made using cold water, the colour of the tea is very pale. Substances dissolve faster as the temperature increases.

Any undissolved substances can be removed from a solution by filtering. When tea is poured from a jug or kettle, a tea strainer can be used to prevent the leaves going in the cup.

Once a substance has been dissolved and filtered, it is usually necessary to remove the solvent. This is commonly done by *evaporation*.

***Example***

Water is evaporated from the salt solution of the sea by the heat of the sun. As more and more water is lost from a solution by evaporation, the salt starts to form crystals. It is these crystals of salt that are packed and sold in the stores.



| Topic 2: Heat Transfer and Thermal Conductivity of Materials | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.9** Examine the basic characteristics of acids, bases, salts and organic and inorganic compounds.<br>**10.3.3.12** Investig`ate how conservation of energy is applied to various systems. |
| **Key question** | • What is conservation of matter?<br>• What is the difference between exothermic and endothermic reactions? |
| **Learning objectives** | By the end of this topic, the students can:<br>• Interpret the law of conservation of matter.<br>• Research and explain exothermic and endothermic reactions with examples. |
| **Vocabulary** | • Reactants, products, endothermic reactions, exothermic reactions |
| **Knowledge** | • The amount of each element in the reactants is equal to the amount of products.<br>• Thermal Conductivity<br>• Law of conservation of matter<br>• Physical and chemical equations<br>• Endothermic and exothermic reactions |
| **Skills** | Careful calculation, Cause and effect of chemical reactions |
| **Attitudes and values** | • Rationality and courage in chemical reactions.<br>• Apply the law of conservation of matter in physical and chemical equations or reations |
| **Teaching and Learning strategies** | Provide hand out and discuss in class, group activity and presentation. |
| **Assessment** | 1. Sulphuric acid is reacted with Calcium hydroxide to produce calcium sulphate, water and heat. Write a word equation, balanced chemical equation with states and explain what type of reaction is this. |
| **Materials** | Sulphuric acid, calcium hydroxide, beaker, test tube, measuring cylinder, gloves, safety goggles |

## Content Background

### Energy and Chemical Change

Chemical reactions which take in heat energy are called *endothermic reactions*. Chemical reactions which give out heat energy are called *exothermic reactions*. ”Therm” means “heat” as in thermometer, “exo” means “out” as in exit and “endo” means “inside”.

*Examples of Endothermic Reactions*

- Cooking
- Heating Substances
  *i.e.* *ron* + *sulphure* + *energy* ⟶ *ron sulphide*
- Photosynthesis
  *i.e.* *cabon dioxide* + *water* + *energy* ⟶ *glucose* + *oxygen*

*Examples of Exothermic Reactions*

- Burning Fuels
  Substances that we burn in air to provide heat and energy are called *fuels*. Firewood, petrol and kerosene are fuels. Fuels contain energy which was stored during the process of photosynthesis. This energy is released when the fuel burns in oxygen.
  *Equation:* *Fuel* + *Oxygen* ⟶ *Heat* + *Light*

- Respiration
  The most important exothermic reaction taking place in our body is *respiration*. Respiration is the chemical reaction which takes place in our cells when glucose reacts with oxygen. As glucose breaks down, the energy stored during photosynthesis is released, and carbon dioxide and water are produced.
  i.e. *glucose* + *oxygen* ⟶ *carbon dioxide* + *water* + *energy*

- BurningElements
  Many exothermic reactions can be carried out in the laboratory, such as the burning of an element in air. For example, when phosphorus is allowed to come into contact with air it catches fire. In magnesium, heat must be supplied before they burn. However, the amount of heat given out is greater than the amount of heat needed to start the reaction, so overall the reaction is exothermic.

  i.e. *magnesium* + *oxygen* ⟶ *magnesium oxide* + *energy*

- Neutralisation
  When an acid is added to a base, a salt and water are produced, and heat is given out. Such reactions are known as neutralization reactions. For example, when hydrochloric acid is added to a solution of sodium hydroxide, the products are sodium chloride and water, and heat is given out.

  i.e. *hydrocholric acid* + *sodium hydroxide* ⟶ *sodium chloride* + *water* + *energy*

**Thermal Conductivity**

Thermal conductivity is the measure of the ease at which heat can pass through a material. A conductor is a material which gives very little resistance to the flow of thermal energy.

Low rate of heat transfer occurs in materials of low thermal conductivity. High thermal conductivity materials transfer heat at a faster rate.

**Factors that affect Thermal Conductivity**

- Temperature Difference
  The greater the difference in temperature, the greater the rate of thermal energy transfer, so more heat will be transferred. The heat, $Q$, is proportional to the difference in temperature $T$:
  Q
- Cross-sectional area
  A material twice as wide conducts twice the amount of heat. In general, the amount of heat conducted, $Q$, is proportional to the cross-sectional area, $A$, of the material:
  $Q \propto A$
- Length (Distance heat must travel)
  The longer the material, the less heat that will make it all the way through. Therefore, the conducted heat is inversely proportional to the length (*e*) of the material:
  $Q \propto \frac{1}{l}$
- Time
  The amount of heat transfer, $Q$, depends on the amount of time that passes, $t$ – twice the time, twice the heat. Mathematically, it is expresses as:
  $Q \propto t$

Some materials that are good and fair/poor conductors of heat are listed in the table below:

Table: Common Conductors

| Good conductors | Fair conductors |
|---|---|
| silver | graphite (carbon) |
| copper | nichrome |
| gold | the human body |
| aluminum | damp skin |
| magnesium | acid solutions |
| tungsten | Salt water |
| nickel | Earth |
| mercury | water vapour in air |
| plantinum | silicon |
| iron | germanium |

| Topic 3: Systems and the Law of Conservation of Energy | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.10** Examine how conservation of energy is applied to various systems. |
| **Key question** | • How is matter and energy conserved? |
| **Learning objectives** | By the end of this topic, the students can:<br>• Research and explain the law of conservation of matter and energy |
| **Vocabulary** | • Reactants, products, matter, conservation |
| **Knowledge** | • Matter is neither created nor destroyed<br>• The amount of each element in the reactants is equal to the amount of products. |
| **Skills** | • Apply law of conservation of energy in numerical terms (as equations)<br>• Critically analyse and explain why energy is neither created nor distroyed |
| **Attitudes and values** | Liberate the fact that matter and energy is neither created nor destroyed. |
| **Teaching and Learning strategies** | Provide handouts and students research further on information given about the topic. |
| **Assessment** | 1. Research and explain in own ways the law of conservation of matter and energy through experiments |
| **Materials** | Coral, shell, calcium oxide, lab report sheets. |

## Content Background

### Conservation of Energy

Energy is neither created nor destroyed but transformed from one form to another and transferred
from one place to another.

### Conservation of matter

In a chemical reaction the products formed contain the same elements as the reactants used. The elements in the reactants are rearranged to form the products. The amount of each element in the reactants is the same as in the products, so matter is neither created nor destroyed during the course of a chemical reaction. This is known as the *Law of Conservation of Matter*.

Example

i.e. *coral or shell* ⟶ *calcium dioxide* + *carbon dioxide*

*100g* ⟶ *560 g* + *440 g*

| Topic 4: Chemical Reactions and Equations | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.5** Name and write chemical formulas and balance chemical equations.<br>**10.3.3.6** Determine and explain the empirical formulas of compounds.<br>**10.3.3.7** Calculate empirical formulas. |
| **Key question** | 1. What are chemical reactions?<br>2. How can we write chemical equations? |
| **Learning objectives** | By the end of this topic, the students can:<br>• Construct chemical diagrams and equations<br>• Identify different types of chemical reactions. |
| **Vocabulary** | • Combination, decomposition, combustion, redox, aqueous solution |
| **Knowledge** | • Chemical reactions can be represented in diagrams, words or formula.<br>• Number of molecules or atoms in the reactants must be equal to the number of molecules or atoms in the products. |
| **Skills** | • Balancing chemical equations,<br>• Identifying types of chemical equations |
| **Attitudes and values** | Value the process of balancing chemical equation. |
| **Teaching and Learning strategies** | Handouts, group discussion, practical lesson, |
| **Assessment** | 1. Write at least one example of combination, decomposition, and single and double displacement, combustion, and redox balanced chemical equations. |
| **Materials** | Sodium, zinc, copper, Chlorine, water, copper sulphate, sodium hydroxide, silver nitrate. |

## Content Background

### Common Types of Chemical Reactions

- Combination
- Decomposition
- Single displacement
- Double displacement
  - i. Precipitation
  - ii. Neutralisation
- Combustion
- Redox

*Combination Chemical Reaction*

Two or more reactants form one product. The reaction of sodium and chlorine to form sodium chloride:

and the burning of coal (carbon) to give carbon dioxide

$$C\ (s) + 0_2\ (g) \longrightarrow CO_2 (g)$$

*Decomposition Chemical Reaction*

Opposite of combination reactions. In decomposition reactions, a single compound breaks down into two or more simpler substances (elements and or compounds). The decomposition of water into hydrogen and oxygen gases:

$$2H_2O\ (l) \longrightarrow 2H2\ (g) + O_2\ (g)$$

and the decomposition of hydrogen peroxide to form oxygen gas and water

$$2H_2O2\ (l) \longrightarrow 2H_2\ (l) + O_2\ (g)$$

*Single Displacement Chemical Reaction*

In single displacement reactions, a more active element displaces (kicks out) another less active element from a compound. For example, if you put a piece of zinc metal into a copper (ii) sulphate solution, the zinc displaces the copper, as shown in the equation:

$$Zn\ (s) + CuSO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + Cu\ (s)$$

The notation (*aq*) indicates that the compound is dissolved in water – aqueous solution. Zinc replaces copper because it is more reactive.

*Double Displacement Chemical Reaction*

In double displacement reactions, or *metathesis reactions*, two species (normally ions) are displaced. Most of the time, this type of reactions occur in a solution, and either an insoluble solid (precipitation reaction) or water (neutralisation reaction) will be formed.

(i) Precipitation reaction is when an insoluble solid in a solution is formed. The insoluble solid is called precipitate.

$$E.g.\ KCl\ (aq) + AgNO_3\ (aq) \longrightarrow AgCl\ (s) + KNO_3\ (aq)$$

The white insoluble solid that's formed is silver chloride.

(ii) Neutralisation reaction is the chemical reaction between an acid and a base. Take a look at the mixing solutions of sulphuric acid and sodium hydroxide:

$$H_2SO_4\ (aq) + 2NaOH\ (aq) \longrightarrow Na_2SO_4\ (aq) + 2H_2O\ (aq)$$

*Combustion Chemical Reaction*

Combustion reaction occur when a compound, usually one containing carbon, combines with the oxygen gas in the air. The process is commonly called burning. Heat is the most useful product of most combustion reactions. Here is the equation that represents the burning of propane:

$$C_3H_8\ (g) + 5O_2\ (g) \longrightarrow 3CO_2\ (g) + 4H_2O\ (l)$$

Propane belongs to a class of compounds called *hydrocarbons*, compounds composed only of carbon and hydrogen. The product of this reaction is heat. Combustion reactions are also a type of redox reaction.

*Redox Chemical Reaction*

Redox reactions, or reduction oxidation reactions, are reactions in which electrons are exchanged:

$$2Na\ (s) + Cl_2 \longrightarrow 2NaCl\ (s)$$

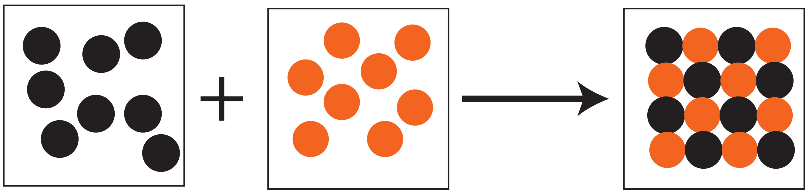
$$C\ (s) + O_2 \longrightarrow CO_2\ (g)$$

$$Zn\ (s) + CuSO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + Cu\ (s)$$

**Representing Chemical Reactions**

Chemical reactions can be represented by particle diagrams, chemical equations and by word equations.

*Particle diagram*
Particle diagrams help us to understand what is happening during a chemical reaction, even though we cannot see that atoms taking part. For example, when iron particles are heated together with sulphur particles, a reaction takes place and particles of iron sulphide are formed.




*Chemical Equations*
Chemical reactions are represented by writing a chemical sentence, which is called a chemical equation. It is a way of representing what happens during a reaction using chemical formulae in place of words.

There are four steps in writing a chemical equation:

1. The reactants and products are written down as a word equation.
2. The formula for each reactant and product is then written underneath each word.
3. An atom check is done by counting the number of atoms of each element one each side of the equation. If the number of atoms on each side is equal, the equation is balanced. The equation must be balanced because matter is conserved during a chemical reaction. If the equation is not balanced, the number of atoms on each side will not be equal.
4. In order to balance the equation. Additional molecules/atoms of reactants or products must be added until the number of atoms on each side is equal.

Example 1: Making Lime

1. Write the word equation

*Calcium carbonate* ⟶ *calcium oxide* + *carbon dioxide*

2. Write the formulae for the reactants and products.

$$CaCO_3 \longrightarrow CaO + CO_2$$

3. Atom Check

| Element | Reactants | Products |
|---|---|---|
| Calcium (Ca) | 1 | 1 |
| Carbon (C) | 1 | 1 |
| Oxygen (O) | 3 | 3 |

The number of atom is equal, so the chemical equation is balanced.

Example 2: Burning Magnesium

1. Write the word equation

$$2Na\ (s) + Cl_2 \longrightarrow 2NaCl\ (s)$$

2. Write the formulae for the reactants and products.

$$2Na\ (s) + Cl_2 \longrightarrow 2NaCl\ (s)$$

3. Atom Check

| Element | Reactants | Products |
|---|---|---|
| Magnesium (Mg) | 1 | 1 |
| Oxygen (O) | 2 | 1 |

The number of atoms is not equal, so the chemical equation is not balanced.

4. Balancing the equation
To increase the number of oxygen atoms on the reactants side, add another magnesium oxide molecule

$$Mg + O_2 \longrightarrow MgO + MgO$$

Atom Check

| Element | Reactants | Products |
|---|---|---|
| Magnesium (Mg) | 1 | 2 |
| Oxygen (O) | 2 | 2 |

The number of atoms is not equal, so the chemical equation is still not balanced.
We must add another magnesium atom to the reactants.

$$Mg + Mg + O_2 \longrightarrow MgO + MgO$$

Atom Check

| Element | Reactants | Products |
|---|---|---|
| Magnesium (Mg) | 2 | 2 |
| Oxygen (O) | 2 | 2 |

The number of atoms is now equal, so the chemical equation is balanced. Collecting like terms together, the final equation is written as:

$$2Mg + O_2 \longrightarrow 2MgO$$

| Topic 5: Elements and Chemical Bonds | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.2** Explain how elements are arranged in the periodic table and analyse trends among elemental properties.<br>**10.3.3.11** Explain how elements are arranged in the periodic table and analyse trends among elemental properties. |
| **Key question** | 1. What are elements?<br>2. What is chemical bonding and how many types are there? |
| **Learning objectives** | By the end of this topic, the students can:<br>• Investigate and explain trends and properties of elements in the periodic table.<br>• Experiment and explain different types of chemical bonding |
| **Vocabulary** | • Covalent, valance electron, combination, displacement, ionic, compound, element |
| **Knowledge** | • Elements are simplest form of matter<br>• A chemical bond is a force of attraction between atoms or ions. |
| **Skills** | • Analysis of periodic table, interpretation of element, constructing bonding diagrams, |
| **Attitudes and values** | • Value that fact that elements are the simplest form of matter.<br>• Appreciate different types of chemical bonding |
| **Teaching and Learning strategies** | • Practical, handout for readings, research, brainstorming.<br>• Show through chemical equation how chloride bond with sodium |
| **Assessment** | 1. How does chloride bond with sodium? |
| **Materials** | A variety of different balls, |

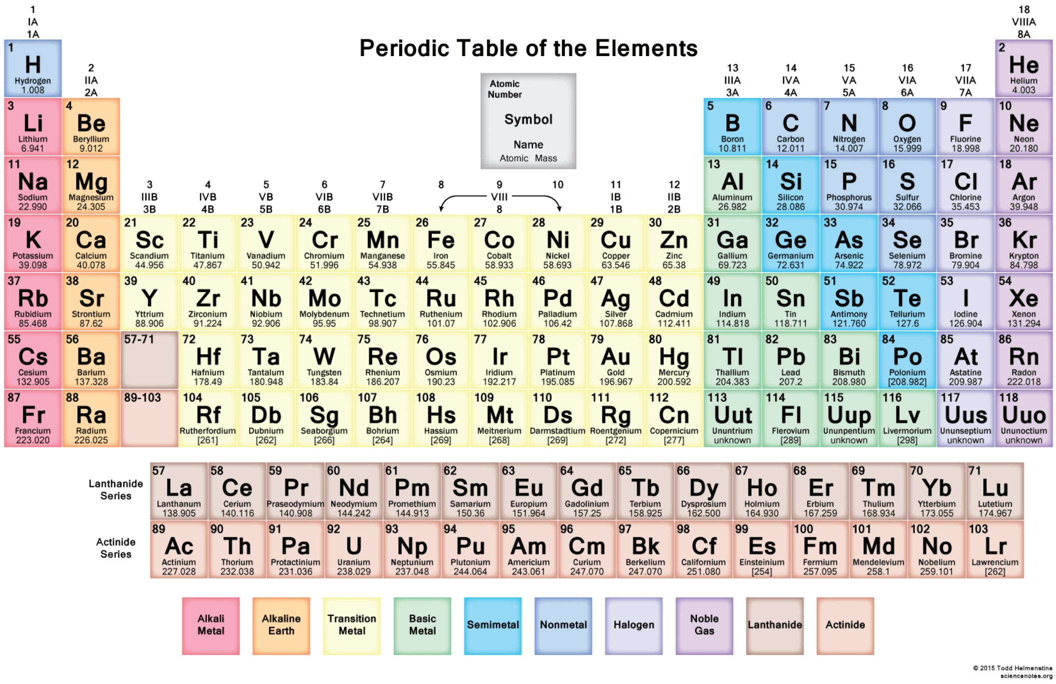
## Content Background

### The Nature of Chemistry

Matter is anything which takes up space and has mass. Matter can also be classified as elements, compounds and mixtures.

Elements are the simplest form of matter. Gold is an example of an element. Compounds are chemical combinations of two or more elements. For example, salt is a combination of the elements sodium and chlorine. Mixtures contain elements and compounds which are not chemically combined. Air is a mixture of gases. Some of the gases, such as oxygen, are elements, while others, such as carbon dioxide are compounds.

Matter is made up of one or more of the 118 known elements. Elements react together to make new substances which have different properties. A critical study of elements has indicated that one way they can be classified is as metals and non-metals.  Elements can also be put into groups which have similar properties. This classification is called the Periodic Table.

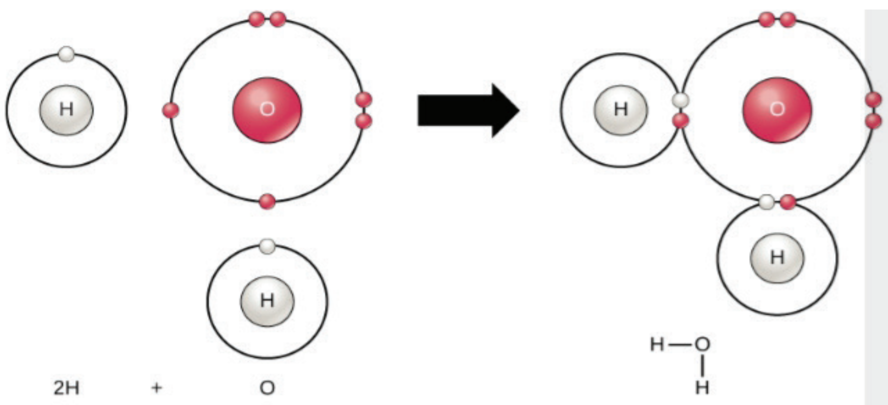



**Chemical Bond**

A chemical bond is a force of attraction between atoms or ions. Bonds form when atoms share or transfer valence electrons. Valence electrons are the electrons in the outer energy level of an atom that may be involved in chemical reaction. Valence electrons are the basis of all chemical bonds.

**Why Chemical Bonds Occur**

To understand why chemical bonds form, let's consider the compound known was water, or $H_2O$. It consists of two hydrogen $(H)$ atoms and one oxygen $(O)$ atom as shown below. Each hydrogen atom has one electron, which is also its sole valence electron. The oxygen atom has six valence electrons. These are the electrons in the *outer energy shell* of the oxygen atom.




Each hydrogen atom shares a pair of electrons with the oxygen atom. By sharing electrons, each atom has electrons available to fill its outer energy level. The hydrogen atoms each have a pair of shared electrons, so their first and only energy level is full. The oxygen atom has a total of eight valence electrons, so its outer energy level is full.

*A full outer energy level is the most stable possible arrangement of electrons*. It explains why elements form chemical bonds with each other.

**Types of Chemical Bonds**

Not all chemical bonds form the same way as the bonds in water. We will actually discuss four different types of chemical bonds; non-polar covalent bonding, polar covalent bonding, hydrogen bonding and ionic bonding.

- Combination Chemical Reaction
- Displacement Chemcial Reaction
- Covalent Bond
- Neutralisation reaction
- Combustion
- Redox Chemical Reaction

### Unit 10.7: Force and Motion

Force is a push, pull or a twist which can be exerted on a body. There are many types of forces which exist around us. Some may be useful and others may have negative effect in our lives.

There are many different types of motion occurring around us all the time. People are walking, cars are being driven along roads, airplanes are flying in the sky, footballs are being kicked, desks are stationary on the floor, and rivers flow downstream, fans spinning on the classroom ceiling, and so on. Thus, movement forms an important part of our everyday life.

In this unit we are going to let students know more about force and motion before they will look at the advance force and motion aspects and application in Gr. 11 physics. This unit consists of four topics:

- Work and simple machines
- Balance and unbalance forces
- Newton's Second and Third Law of Motion
- Fluid Forces

All these topics are linked to upper secondary physics content and set the foundation for force and motion in upper secondary and beyond.

| Topic 1: Work and Simple Machines | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.13** Apply the law F = ma to solve one dimensional motion problems that involve constant forces (Newton's second law). |
| **Key questions** | 1. What is work and name its units?<br>2. How do simple machines do work? |
| **Learning objectives** | By the end of this topic, students can:<br>• Define work and give examples<br>• Investigate different types of machines and describe their functions. |
| **Vocabulary** | Work, power, energy, velocity ration, mechanical advantage, efficiency, pivot, fulcrum, pulley, gear, wheel, axle |
| **Knowledge** | • Work is done when a force moves an object through a distance in the direction of the force.<br>• The rate at which work is done is called the power<br>• The efficiency of a mechine is always less than 100 % because of friction. |
| **Skills** | Categorise, combine, design and modify simple machines. |
| **Attitudes and values** | • Creativity in designing simple machines,<br>• Adaptable to change in in creating machines that suit community lifestyle. |
| **Teaching and Learning strategies** | Debate, discuss, project, media and technology. |
| **Assessment** | 1. A man uses a crowbar 1.5 m long to lift a rock weighing 600 newtons. If the fulcrum is 0.5 m from the end of the bar touching the rock, how much effort must the man apply? (Draw a diagram first). |
| **Materials** | Paper, wheel, axle, bar (for lever), screw, pulley (if available or else use diagrams) rocks |

**Work**

Jayden works in a supermarket. His job is to fill up shelves when they are empty. When Jayden lifts up tins to put on the shelves he is doing some work. The amount if work Jayden does depends on how far he lifts the tins and how heavy they are.

$$\textit{Work done} = \textit{force} \times \textit{distace} = F \times d$$

Work is hence, defines as:

Work is measured in *joules* (*J*). 1 joule of work is done when a force of 1 newton moves something through a distance of 1 metre, in the direction of the applied force.

$$1\ J = 1\ N \times 1\ m$$

Example

How much work does Jayden do when he lifts a tin with a weight of 20 N through a height of 0.5 m?

$$W = F \text{ x } d$$
$$= 20\ N \text{ X } 0.5 \text{ m}$$
$$= 10\ J$$

Jayden does the same amount of work when he lifts a tin with a weight of 10 N through 1 m.

**Does a force always do work?**

The answer to the question above is NO! In the figure below, Samantha is doing some weight training. She is holding two weights, but she is not lifting them. She becomes tired because her muscles use energy, but she is not doing any work, because the weights are not moving. To do work, you have to do something useful, like lifting the load but not just holding them.

**Energy**

To further explain the application of work, we need to take into consideration energy. You have to put fuel into a machine to make it work. We say that the fuel has got some energy. For example, 1 litre of petrol has 40 million joules of energy stored in it.

**Different Types of Energy**

- Refer to Gr. 9 to review different types of energy

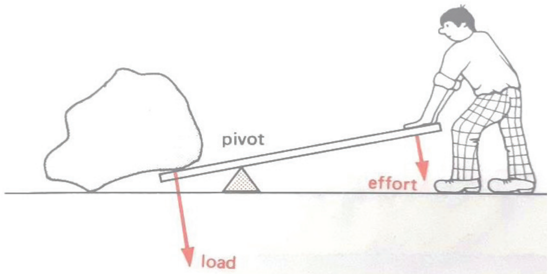
**Power**

A small engine can do just as much work as a larger engine, but it takes longer to do it. The larger engine can do work at a faster rate. The Rate at which work is done is called*power*.

$$\text{power} = \frac{\text{work done}}{\text{time taken}} \quad \text{or} \quad \frac{\text{energy transfered}}{\text{time taken}}$$

**Simple Machines**

A lever is a very common simple machine. The diagram shows a crowbar being used to lever up a large stone.

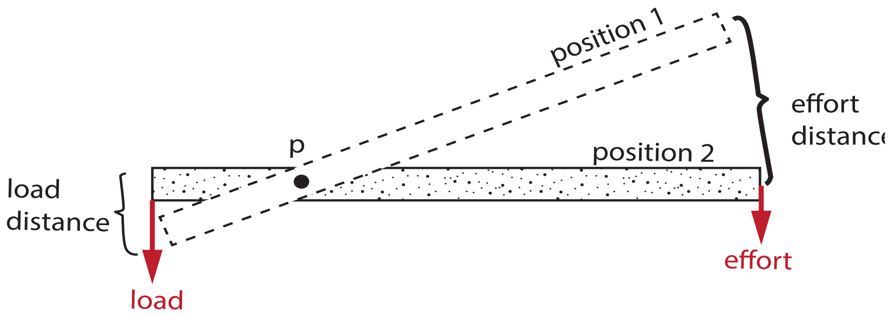



The man is exerting an *effort* force, against a *load* force (the weight of the stone. As you can see in the diagram, the force of the man is *smaller* than the load force of the stone because he is pushing a *longer* distance from the pivot.

This means that the lever is magnifying the force. To see how much it magnifies the force, we calculate the *mechanical advantage (M.A.)*.

$$\text{Mechanical advantage (M.A)} = \frac{\text{work done}}{\text{time taken}}$$

Although the man does not have to push as hard as the load, he has to push further. As the diagram shows, the distance moved by the force is greater than the distance moved by the load. The ratio of these two distances is called the *velocity ratio (V.R.)*.




$$\textit{Velocity Ratio (V.R)} = \frac{\textit{distance moved by the effort}}{\textit{distance moved by the load}}$$

**Efficiency**

The efficiency of a machine is very important. If we could build a machine that had no friction in it, then it would be 100% efficient and all the energy put into the machine (by the effort) would get out of the machine (and given to the load).

In practice, all machines have some friction in them and work got out is always less than the work put in.

$$\textit{\% Effeciency} = \frac{\textit{work got out (work done on the load}}{\textit{work put in (work done by the effort)}} \times 100\ \%$$

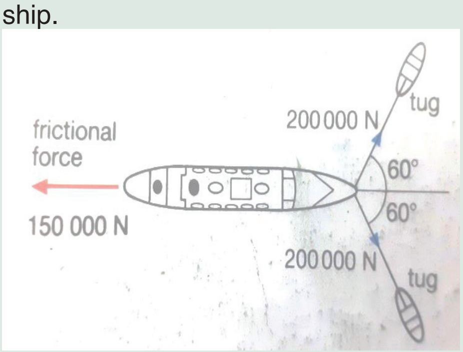
The efficiency is always less than 100 % because of friction.

From the formula for % efficiency it can be proved that:

$$\textit{\% Effeciency} = \frac{M.A}{V.R} \times 100\ \%$$

Other types of simple machines to study are:

- Wheel and Axle
- Gears
- The incline Plane
- The Screw
- Pulleys

| Topic 2: Balance and Unbalanced Forces | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.14** Verify that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law). |
| **Key question** | 1. What are balanced and unbalanced forces?<br>2. Can forces be added? |
| **Learning objectives** | By the end of this topic, students can:<br>• Explain the characteristics of balanced and unbalanced forces.<br>• Describe forces as vector quantities to get resultant or net forces acting on a body. |
| **Vocabulary** | • Vector, scalar, resultant force, net force, weight , mass, friction |
| **Knowledge** | • When two forces acting on an object are equal in size but act in opposite directions, we say that they are balanced forces.<br>• When two objects acting on an object are not equal in size, we say that they are unbalanced forces.<br>• *weight = mass x pull of gravity* |
| **Skills** | • Comparing and constructing, Analysing, visualising, and problem solving skills involving forces. |
| **Attitudes and values** | • Sensitivity in solving force related problem<br>• Confident and corporative |
| **Teaching and Learning strategies** | • Performance related tasks, discussion, games and simulations |
| **Assessment** | 1. The diagram shows a large ship being pulled by two tugs. As the ship moves through the water there is a frictional force that acts on it. Work out the resultant force of the ship.<br><br> |
| **Materials** | • Masses, diagrams of types of forces, charts or handouts of information. |

## Content Background

### What is a Force?

A force is a push, pull or a twist. Whenever you push, pull or twist an object you are exerting a force on it. The forces you exert can cause three things:

- Change the shape of N OBJECT. E.g., stretching or squashing a spring or bending and breaking a ruler.
- Change the speed of an object. E.g., increasing the speed of the ball when it is thrown and decreasing its speed when it's caught.
- Change the direction in which an object is travelling. E.g., A steering wheel to turn a car.

**Type of forces**

There are a variety of different types of forces. We will place these forces into two broad categories as contact or non-contract forces.

| Contact forces | Non-contact forces |
|---|---|
| Frictional Force | Gravitational Force |
| Tension Force | Electrical Force |
| Normal Force | Magnetic Force |
| Air Resistance | |
| Force | |
| Applied Force | |
| Spring Force | |

**Two important forces**

The pull of gravity and friction are two forces that we notice everyday of our lives.

*Weight*

Weight is the name that we give to the pull of gravity of an object. Near the earth's surface the pull of gravity is 10 N on each kilogram. We say that the earth's gravitational field strength is 10 N/kg. E.g., What is your weigh if your body has a mass of 50 kg?

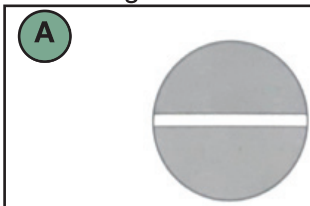
$$\begin{aligned} weight &= mass \times pull\ of\ gravity \\ &= 50\ k \times 10 \frac{N}{kg} \\ &= 500\ N \end{aligned}$$

*Friction*

Friction is the contact force that slows down moving things. Friction can also prevent stationary things from starting to move when their forces act on them. All surfaces are not perfectly as smooth even though when observed by naked eyes. If you look through a powerful microscope you will be able to see that it has many rough spikes and edges. When two surfaces move past each other, these rough spikes catch onto each other and slow down the motion.

How two surfaces appear when seen through a powerful microscope.

*Reducing friction*




If the surfaces are highly polished, friction is less.


A layer of oil between two surfaces acts as a cushion to stop the edges rubbing each other.

**Balanced Forces**
When two forces acting on an object are equal in size but act in opposite directions, we say that they are *balanced forces*. If the forces on an object are balanced (or if there are no forces acting on it), this is what happens:

- A stationary object stays still.
- A moving object continues to move at the same speed and in the same direction.

Remember that an object can be moving, even if there are no forces acting on it.
Teacher to mention also:

- Force diagram
- Hanging objects
- Floating in water
- Standing on the ground

**Unbalanced Forces**
When two objects acting on an object are not equal in size, we say that they are unbalanced forces. The overall force acting on the object is called the resultant force. If the forces are balanced, the *resultant force* or *net* force is zero. If the forces on an object are unbalanced, this is what happens:

- A stationary object starts to move in the direction of the resultant force.
- A moving object changes speed and/or direction in the direction of the resultant force.

**Vectors and Scalars**
If you want to move a soccer ball, you have to give it a kick. The direction in which the ball moves depends on the direction of your kick. A hard kick will move the ball quickly and further. So both the *direction* and the *size* of a force are important.

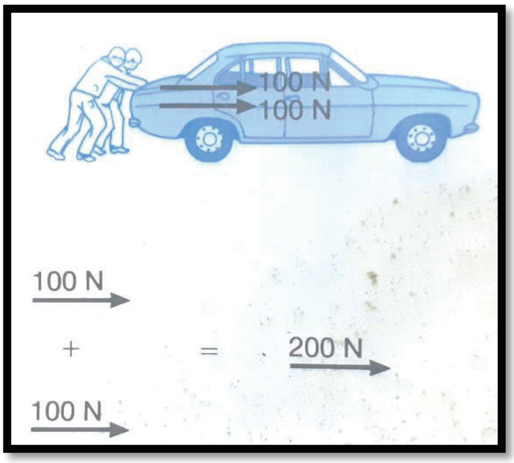
Force is a *vector*. Vector quantities have both size and direction. Other examples of vector quantities are velocity (wind 50 km/h north), displacement (2 paces backwards), acceleration and momentum.

A quantity that has only a size is called a *scalar*. Some examples of scalar quantities are: mass (2 kg of oranges), temperature (20$^{O}$C) and energy (100 J).

**Adding Forces**

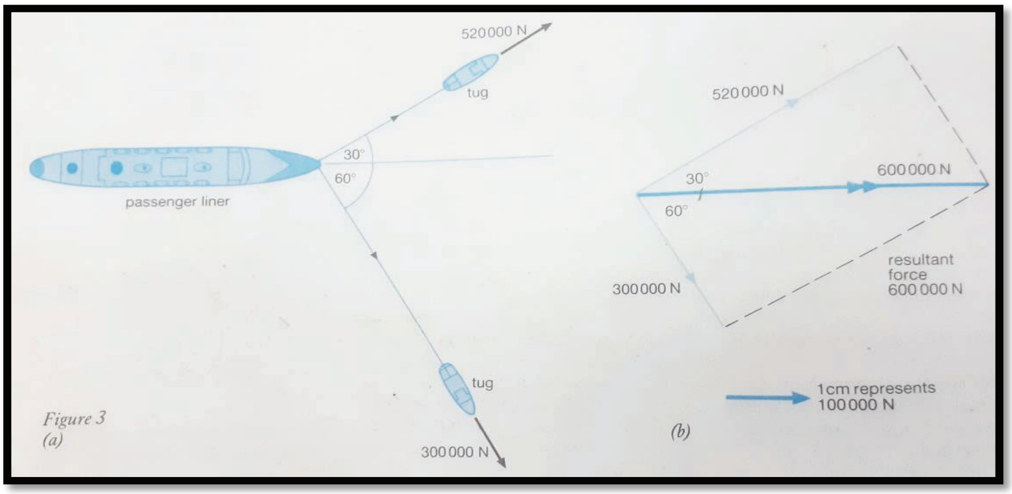
Adding scalars is always easy: $3\ kg\ of\ apples\ +\ 3\ kg\ of\ apples\ =\ 6\ kg\ of\ apples$.
Adding vectors can be a little herder. Here are three examples of adding vectors.

1. When two forces act in the same direction, they add up to give a larger resultant or net force. In this case $100\ N\ +\ 100\ N\ =\ 200\ N$.




2. In the second example, the driver has left the car hand break on. Your push of 100 N to the right is cancelled out by a frictional force acting to the left. The resultant force is zero.


3. In figure below, you can see two tugs pulling a passenger liner into port. To work out the resultant force in this case we need to make a scale drawing. The first step is to choose a scale. We will make a length of 1 cm represent a force of 100 000 N. The lines representing the forces are then drawn to scale. Then two more lines are drawn to complete the parallelogram. The resultant force can now be worked out by drawing the line across the diagonal of the parallelogram. In this example, the line is 6 cm long, so the resultant force on the liner is 600000N. You can see that the direction of this resultant force pulls the linear straight ahead.



## Topic 3: Newton's Second and Third Laws of Motion

| | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.13** Apply the law F = ma to solve one dimensional motion problems that involve constant forces (Newton's second law).<br>**10.3.3.14** Verify that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law). |
| **Key question** | 1. What do you know about Newton?<br>2. How many motion laws did Newton discover? |
| **Learning objectives** | By the end of this topic, students can:<br>• Analyse and apply Newton's second and third laws.<br>• Investigate and explain the application of Newton's motion laws in their daily lives. |
| **Vocabulary** | Vector sum, horizontal direction, vertical direction, |
| **Knowledge** | • Every object can only accelerate if there is an applied force on the object.<br>• To every force there is an equal and opposite force. |
| **Skills** | Generating ideas, predicting, visualising and application of Newton's motion laws. |
| **Attitudes and values** | • Equality and trust.<br>• Critical and appreciative |
| **Teaching and Learning strategies** | Research, practical, debate, handouts, discussions. |
| **Assessment** | 1. Investigate in your community an activity that occurs which involves one of the two Newton's law. Present your findings to the class. |
| **Materials** | Chart, diagrams, handouts, marker,lab report sheets. |

## Content Background

### What is Newton's Second Law?

In the world of introductory physics, Newton's second law is one of the most important laws you will learn. It's used in almost every chapter of every physics textbook, so it's important to master this law as soon as possible. We know every objects can only accelerate if there forces on the object. Newton's second law tells us exactly how much an object will accelerate for a given net force.

To be clear, $a$ is the acceleration of the object, *F* is the net force on the object, and *m* is the mass of the object. But we always though that Newton's second was *F=ma.*

Looking at the form of Newton's second law shown above, we see that the acceleration is proportional to the net force, *F* and is inversely proportional to the mass, *m*. in other words, if the net force were doubled, the acceleration of the object would be twice as large. Similarly, if the mass of the object were doubled, its acceleration would be half as large.

### What does net force mean?

A force is a push or a pull, and the net force *F* is the total force – or sum of the forces- exerted on an object. Adding vectors is a little different from adding regular numbers. When adding vectors, we must take their directions into account. The net force is the ***vector sum*** of all the forces exerted on an object.

**What does the term vector sum mean?**

Insert sheep diagram including forces exerted.

For instance, consider two forces of magnitude 30N and 20N that are exerted to the right and left respectively on the sheep shown above. If we assume rightward is the positive direction, the net force on the sheep can be found by;

$$F = \overrightarrow{30}\,N + \overleftarrow{20}\,N$$
$$F = \overrightarrow{10}\,N$$

If there were more horizontal forces, we could find the net force by adding up all the forces to the right and subtracting all the forces to the left. Since force is a vector, we can write Newton's second law as ________________This shows that the direction of the total acceleration vector points in the same direction as the net force vector. In other words, if the net force Σ*F* points right, the acceleration *a* must point right.

**How do we use Newton's second law?**
If the problem you're analysing has many forces in many directions, it's often easier to analyse each direction independently. In other words, for the horizontal direction we can write

$$a_x = \frac{F_x}{m}$$

This shows that the acceleration $a_x$ in the horizontal direction is equal to the net force in the horizontal direction, $F_x$, divided by the mass.

Similarly, for the vertical direction we can write

$$a_y = \frac{F_y}{m}$$

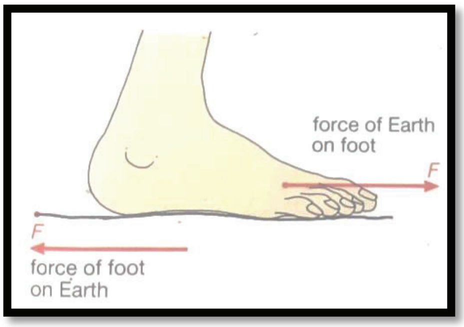
This shows that the acceleration $a_y$, in the vertical direction is equal to the net force in the vertical direction, $F_y$, divided by the mass.

When using these equations we must be careful to only plug *horizontal* forces into the *horizontal* form of Newton's second law and to plug *vertical* forces into the *vertical* form of Newton's second law. We do this because horizontal forces only affect the horizontal acceleration and vertical forces only affect the vertical acceleration.

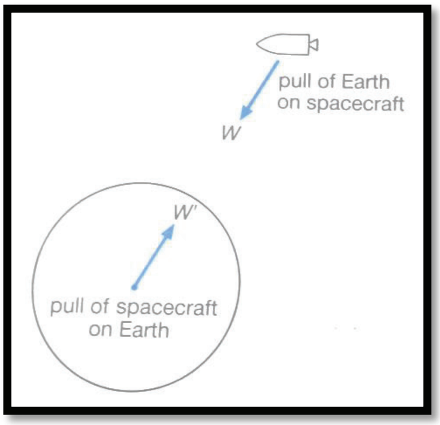
**Newton's Third Law of Motion**

Newton's third law states that *to every force there is an equal and opposite force*. So forces always occur in pairs. This may sound easy to apply, but there are also few concepts to and techniques to master. Some examples of the application of Newton's third law are:

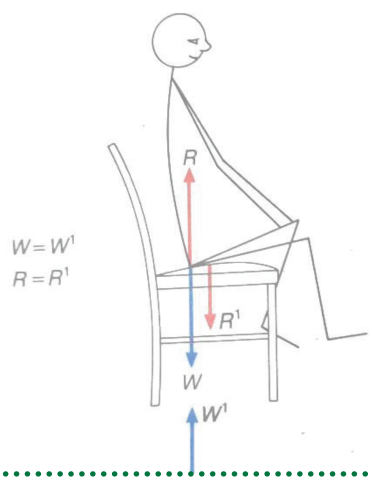
- When you walk, the Earth pushes your foot forwards; your foot pushes back on the Earth.

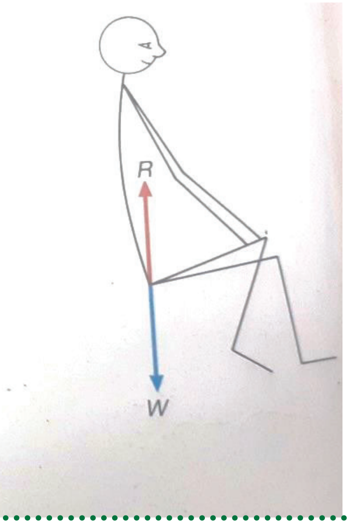



- A spacecraft returning to Earth is pulled downwards. The spacecraft pulls the Earth back. This means that as the spacecraft moves, the Earth moves too. But the Earth is so big that it moves only a tiny amount – far too little for us to notice.




A man sitting on a chair. There are two pairs of forces to think about. The Earth's gravitational pull on the man is $W$. The man's gravitational pull on the Earth is $W^1$. The chair exerts a reaction force $R$ on the man. He exerts a force $R^1$ on the chair.



| Topic 4: Fluid Forces | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.15** Explore the behaviour of different types of Fluids |
| **Key question** | • What is a fluid?<br>• Name some fluids that are useful? |
| **Learning objectives** | By the end of this topic, students can:<br>• Analyse different types of fluids and the forces they exert?<br>• Explain pressure and density of some common fluids? |
| **Vocabulary** | Specific gravity, relative density, pressure, density |
| **Knowledge** | Specific gravity is the ratio of the density of a substance to that of a standard substance.<br>$P = \frac{F}{A}$ |
| **Skills** | Analysing, categorising |
| **Attitudes and values** | Interdependence and courage.<br>Appreciative and creative |
| **Teaching and Learning strategies** | Observation, case study, research, projects or practials |
| **Assessment** | • Use nails to pierce 3 different holes vertically at different heights. Pour water in and observe how the water escapes out of the holes. Write a report or discuss in groups and explain their observations. |
| **Materials** | Tin fish tin, nail, water, Lab report sheets |

## Content Background

### Density and Pressure

*What is Density?*

- Density is the mass per unit volume of an object or $\rho = \frac{m}{V}$ where, $\rho$ is density, $m$ is mass and $V$ is the volume of an object volume.

*Specific Gravity*

- Specific gravity is the ratio of the density of a substance to that of a standard substance. Specific gravity is also referred to as relative density.

$$\text{specific gravity} = \frac{\text{density of object}}{\text{density of water}}$$

## Density and Pressure

*What is Density?*

- Density is the mass per unit volume of an object or $\rho = \frac{m}{V}$ where, $\rho$ is density, $m$ is mass and $V$ is the volume of an object volume.

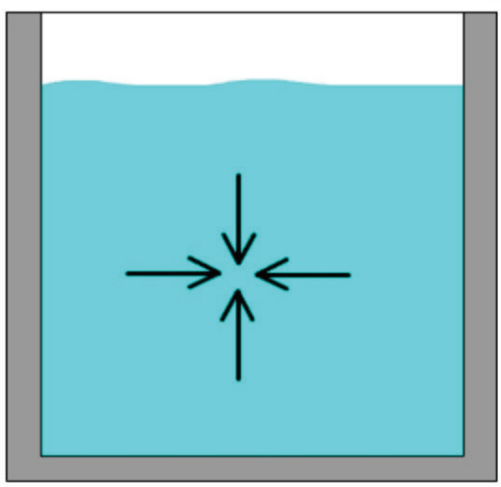
*Specific Gravity*

- Specific gravity is the ratio of the density of a substance to that of a standard substance. Specific gravity is also referred to as relative density.

$$\text{specific gravity} = \frac{\text{density of object}}{\text{density of water}}$$

*What is fluid pressure?*

- Fluid pressure is a measurement of the force per unit area of an of an object in the fluid or on the surface of a closed container. The pressure can be caused by gravity, acceleration, or by forces outside a closed container. Since a fluid has no definite shape, its pressure applies in all directions. Pressure is defined as force divided by the area on which the force is pushing. i.e., $P = \frac{F}{A}$ where, $P = \text{pressure}, F = \text{force}, A = \text{area}$



Water pressure is the same in all directions

*Swimming underwater*

When you swim under water, the pressure of the water gets greater on your body, the deeper you get. Why aren't you crushed by this weight? The reason is that your body compensates by creating an internal pressure that is equal to the air or water pressure. Now when you go very deep under water, the water pressure may get greater than your body can compensate for, and you get uncomfortable.

pressure to an object in its way proportional to the surface area perpendicular to the direction of motion. Streamlining the object reduces this pressure.

*Heating and Chemical Effects*
When you heat a fluid, it usually expands. If you heat a fluid that is in enclosed container, the expansion will result in greater internal pressure. For example heating a balloon will cause it to expand.

Likewise, chemical reactions that give off gases will increase the pressure inside the container. For example, shaking a coke bottle releases more gas and will result in greater internal pressure. This can be experienced when you open the bolted the drink rushes out all over.

## Unit 10.8: Waves, Electricity and Magnetism

Energy is often moved from one place to another by waves. You can see this if you throw a stone into a pond. Waves spread out from the splash and soon the water at the edge of the pond moves as it gets some of the energy of the splash. There are generally two different kinds of waves which we are going to further investigate in this unit.

Magnetism and electricity will be collaborated when teaching the unit and topics to the students. Magnetism will set the foundation for students to understand the principles and applications of electricity.
In this unit, we are also going to study a number of different types of electricity. Some types of electricity are produced naturally and humans also produce electricity in a number of ways. For example, during a storm, lightning can light up the whole sky and the sound of thunder that follows can be quite frightening.
We can see and hear the large amounts of light and sound energy that are produced. Some fish can also produce electricity. For example, electric rays can produce an electric discharge that is strong enough to kill their prey or make them unconscious. Other form of electricity will also be discussed as we go through the topic of this unit.

| Topic 1: Mechanical Waves | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.16** Investigate the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization. |
| **Key question** | 1. What are mechanical waves?<br>2. When do we experience waves and give some examples? |
| **Learning objectives** | By the end of this topic, students can:<br>• Describe different types of mechanical waves.<br>• Investigate and explain waves using their properties. |
| **Vocabulary** | • Transverse, longitudinal, crest, trough, wavelength, slinky spring |
| **Knowledge** | • Transverse waves are waves that the energy vibrates at right angles to the source and longitudinal waves are waves that the energy vibration is parallel or in line with the source. |
| **Skills** | • Comparing and contrasting, evaluating |
| **Attitudes and values** | • Sensitivity and affectivity<br>• Critical, creative and appreciative of wave properties and applications in real life situations. |
| **Teaching and Learning strategies** | • Practical, project, discussions, observations and games and simulations. |
| **Assessment** | Place a thick piece of glass in a ripple tank and adjust the depth so that the water is very shallow over the piece of glass. Send waves across the tank and observe the waves as they travel through the shallow water. What do you see? What happens to (a) the velocity and (b) the wave length of the waves when they move into the shallow water? |
| **Materials** | Water, ripple tank ( or any clear tanks), piece of thick glass, lab report |

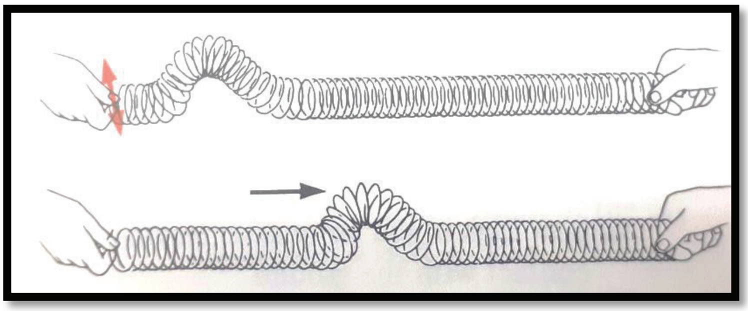
## Content Background

### Mechanical Waves

Waves which propagate through a material medium such as a gas, solid or liquid are referred to as mechanical waves. The speed at which the waves travel through a medium depends on the properties of the medium. Some examples of mechanical waves are sound waves and water waves. There are two main kinds of waves, *transverse* and *mechanical* waves.

*Transverse waves*

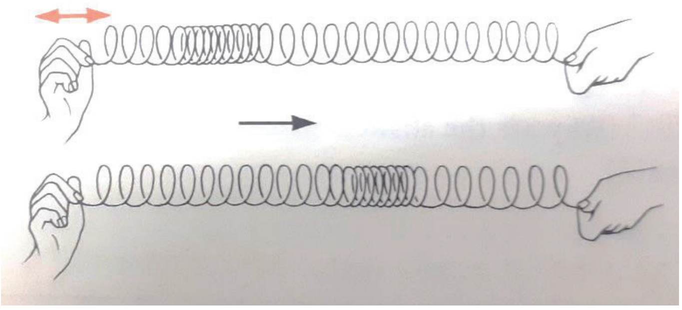
To see a transverse wave, stretch a long slinky spring along a smooth bench or floor and then give one end a quick wiggle *at right angles* to the spring.



You can see that energy is moving down the spring although each bit of the spring is only vibrating. It is vibrating at right angles (*transversely*) to the spring.

*Longitudinal waves*

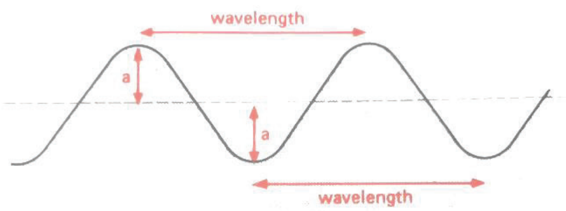
Stretch the same slinky spring along the floor and this time give it a quick wiggle to and fro *along the length* of the spring.



If you look closely you can see that the energy is passing down the spring although each bit of the spring is only vibrating. It is vibrating lengthways or *longitudinally*.

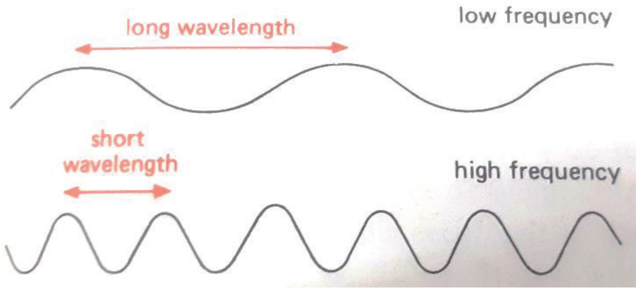
### Properties of waves

Here is a side view of a transverse water wave:

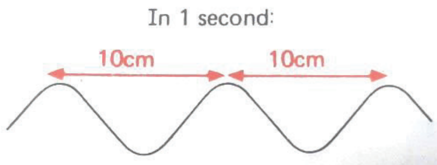



The high parts are called the *crest* and the low parts are called *troughs*. The distance marked $a$ is called the *amplitude*. It is the height of a crest above the average water level. The distance between two successive crests (or troughs) is called the *wavelength*. The number of successive waves per second is called the *frequency*. The unit for frequency is the hertz, Hz.

At low frequency, the wavelengths are longer and at high frequency, the wavelengths are shorter. Regardless, of high and low frequency, you will notice that the velocity remains the same.




*Example*
A wave has a frequency of 2 hertz (two cycles per second) and a wave length of 10 cm. What is the velocity of the wave?



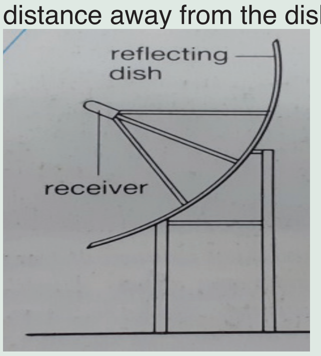

In each second, two waves are produced, each of length 10 cm.
Therefore, the wave travels forward 20 cm in each second. That is, the velocity of the wave is 20 cm/s.

In fact for any wave:

$$\underset{(m/s)}{velocity} = \underset{(Hz)}{frequency} \times \underset{(m)}{wavelength}$$

Teacher to go through experiments of ripple tank explaining

- Reflection on a straight barrier
- Reflection at a curved (concave) barrier
- Reflection at a curved (convex) barrier
- Refraction of wave

| | |
|---|---|
| **Topic 2: Electromagnetic Waves** | |
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.17** Explain and provide examples of electromagnetic radiation and sound using a wave model. |
| **Key question** | 1. What is electromagnetic wave?<br>2. Do you think electromagnetic waves behave water waves? |
| **Learning objectives** | By the end of this topic, students can:<br>• Identify and describe the electromagnetic spectrum.<br>• Investigate and explain electromagnetic waves using their properties. |
| **Vocabulary** | Electromagnetic spectrum, electromagnetic, magnetic force, electric force |
| **Knowledge** | In a vacuum, all electromagnetic waves travel at a speed of $3 \times 10^8 m/s$ but at different speed through other mediums. |
| **Skills** | Analyse and categorize electromagnetic waves. |
| **Attitudes and values** | Creativity and rationality in understanding the electromagnetic waves<br>Critical and optimistic |
| **Teaching and Learning strategies** | Group discussion, practical, projects, quiz |
| **Assessment** | The diagram shows a side view of a radio dish. Explain why the receiver is placed some distance away from the dish.<br> |
| **Materials** | Handouts, charts, |

## Content Background

**Electromagnetic Waves**

There are many sort of electromagnetic wave, which produce different kinds of effect. Figure below shows the full *electromagnetic spectrum*. The range of wavelengths in the spectrum stretches from $10^{-12}\ m$ for gamma rays to about $2\ km$ for radio waves.

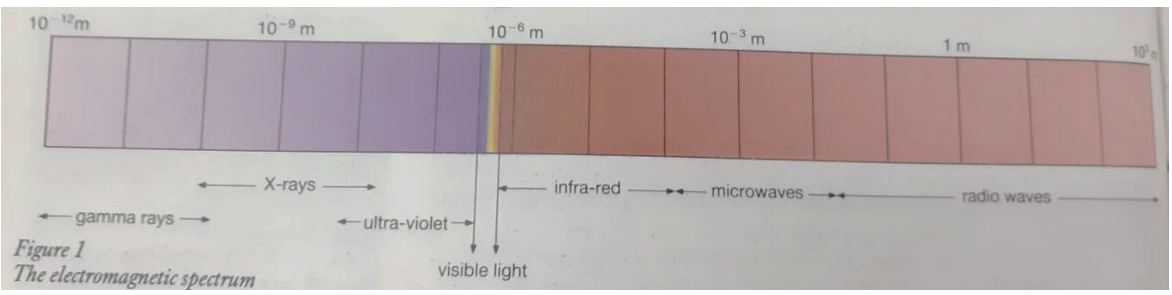



*Figure 1*
*The electromagnetic spectrum*

All the waves you have met and will come across travel through some material. Sound waves travel through air, seismic waves travel through Earth; water ripples travel along the surface of water. Electromagnetic waves can travel through a vacuum; this is how energy reaches us from the Sun. The energy is carried by changing electric and magnetic forces. These changing forces are at right angles to the direction in which the wave is travelling. So electric waves are transverse waves.

Electromagnetic waves show the usual wave properties. They can be reflected, and refracted. They show diffraction and interference effects. In a vacuum all electromagnetic wave travel at a speed of $3{\times}10^{8}\ m/s$. However, electromagnetic waves do not all travel at the same speed when they travel in a material. For example, different colours of light travel at different speed in glass.

***Teacher to discuss the properties, behaviours and applications of:***

- *Radio waves*
  Wavelengths and frequencies for different types of radio waves

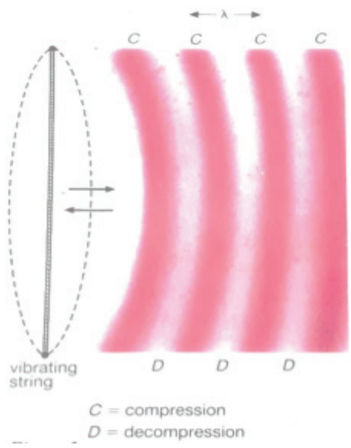
| Topic 3: Sound Waves | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.16** Investigate the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization. |
| **Key question** | 1. What is sound and how is it produced?<br>2. What are some properties of waves you know of from the previous topic? |
| **Learning objectives** | By the end of this topic, students can:<br>• Research and describe sound waves using their properties.<br>• Identify and explain different types of sound waves. |
| **Vocabulary** | • Pitch, loudness, quality of sound, ultrasonic, |
| **Knowledge** | • Sound is determined by the loudness, quality and pitch. |
| **Skills** | • Deconstructing and reconstructing sound wave forms. |
| **Attitudes and values** | • Courageous and creativity in presenting wave forms.<br>• Rationality and simplicity in explaining sound waves to others. |
| **Teaching and Learning strategies** | • Project, media and technology, observation, discussion |
| **Assessment** | 1. Explain why it is necessary to have laws controlling the noise level near airports. |
| **Materials** | Charts, graph papers, diagrams, |

## Content Background

### Sound Waves

Sound is a longitudinal wave. Molecules in air move backwards and forwards along the direction of the sound travels in.

Figure  on the right shows a vibrating guitar string.



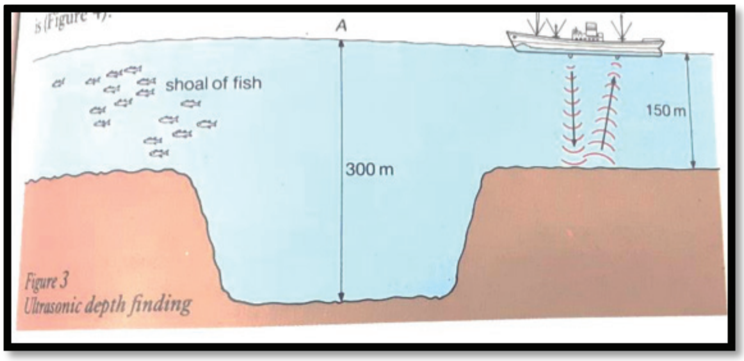

When the guitar string moves to the right, it compresses that air on the right hand side of it. When the strings move to the left the air on the right expands. The string produces a series of *compressions* and *decompressions*. In a compression the air pressure is greater than the normal atmospheric pressure. In a decompression, the air pressure is less than the normal atmospheric pressure.

### Speed of Sound

The speed of sound depends on which material it travels through. Sound waves are transmitted by molecules knocking into each other. In air sound travels at 330 m/s. In solids and liquids, where molecules are packed more tightly together, sound travels faster. In a vacuum there are no molecules at all. Sound cannot travel through a vacuum, although light can.

### Ultrasonic and Depth finding

We use the name *ultrasonic* to describe very high frequency sound waves. These waves have such a high frequency that we cannot hear them. Because ultrasonic has a high frequency, the waves have a short wavelength. This means that it is possible to produce a narrow beam of ultrasound without it spreading out due to diffraction effects.

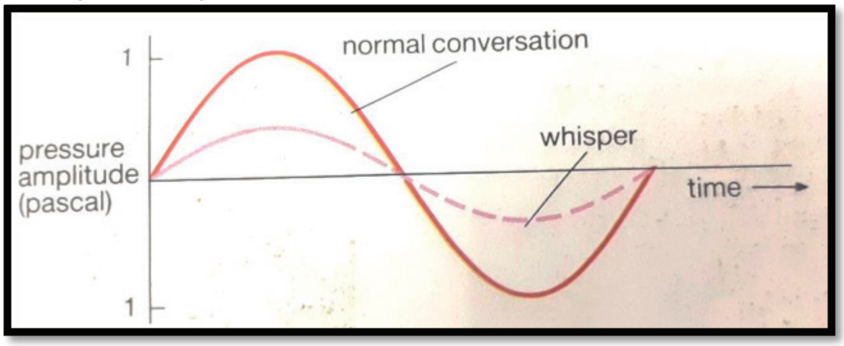



Ultrasonic depth finding.

**Loudness, Quality and Pitch**

*Loudness*

Ears detect a sound over a wide range of frequencies. You can hear frequencies as low as 20 Hz, and as high as 20 000 Hz. Ears are most sensitive to frequencies of about 2000 Hz. The loudness of a noise depends on the pressure caused by the soundwave. Loud noise can be very unpleasant and can damage hearing.




Sound waves caused by human voice.

*Quality*

The quality of a note depends on the shape of its waveform. Although two notes may have the same frequency and amplitude, if their waveforms are of a different shape, you will detect a different sound.

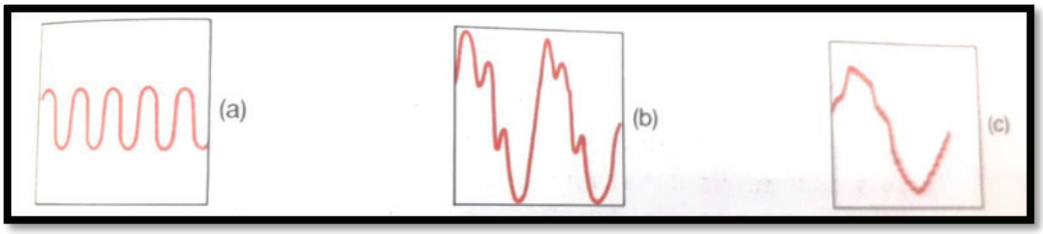
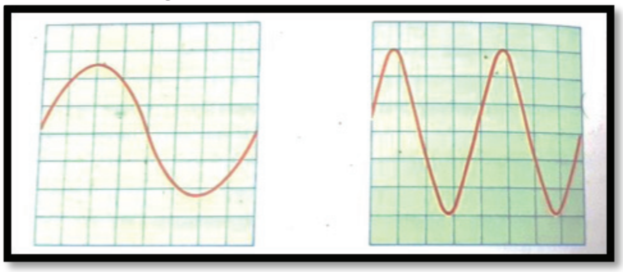



Figure above shows different waveforms produced by three different musical instruments. The notes have different qualities.

*Pitch*

We use the term pitch, to describe how a noise or a music note sounds to us. Bass notes are of low pitch, terrible notes are of high pitch. Men have low-pitched voices; women have voices of higher pitch. The higher-pitch notes are the notes with higher frequency.



(a) Low pitch (b) High pitch.

| Topic 4: Properties of Light | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.18** Establish that radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately $3 \times 10^8$ m/s (186,000 miles/second). |
| **Key question** | • What is a light?<br>• What are some sources of light? |
| **Learning objectives** | By the end of this topic, students can:<br>• Investigate and explain the nature and the properties of light. |
| **Vocabulary** | • Photosynthesis, Luminous, Non-luminous, Artificial and natural light, phosphorescence, visible spectrum |
| **Knowledge** | • Light consists of particles that travel in straight line.<br>• Light like radio energy, travel by means of wave. |
| **Skills** | Evaluating and making informed conclusion on the nature and properties of light. |
| **Attitudes and values** | • Trust and truth in explaining the properties of light.<br>• Critical and creative in in advocating others about light. |
| **Teaching and Learning strategies** | Discussion, project, Media and technology. |
| **Assessment** | 1. Research and present findngs on the dual theory of light. |
| **Materials** | Butcher papers, markers, handouts, diagrams,lab report |

## Content Background

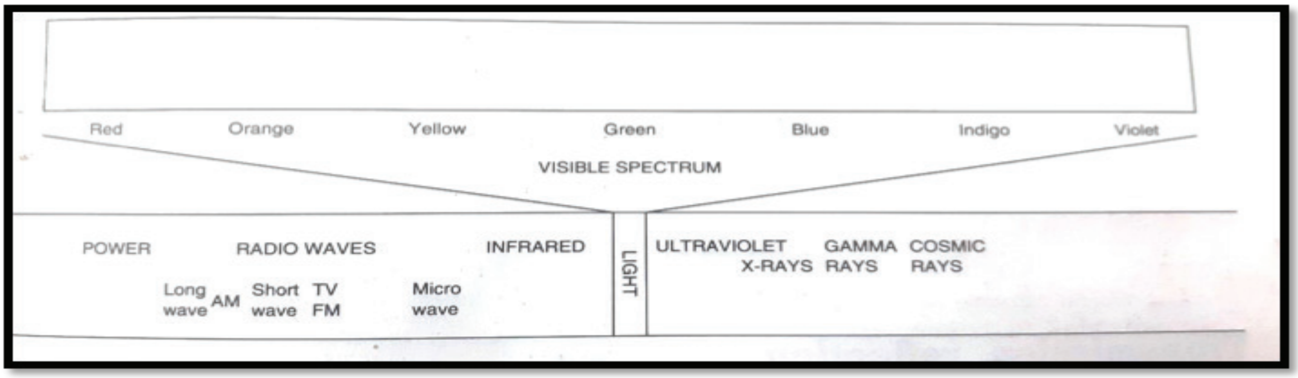
### The Nature and Properties of Light

Without light from the Sun there would be no life on the Earth. Plants use life energy from the Sun to make food. Carbon dioxide and water are combined using light energy to make glucose first and then starch. This process is called *photosynthesis* and is very important to all living things.

Light is also the form of energy which enables us to see with our eyes. When light energy passes into our eyes we can see. When no light energy enters our eyes, everything appears black.

**Source of light**

- Luminous Objects
  - objects that give out their own light.
- Non-luminous objects
  - objects that do not produce their own light
- Natural source of light
  Lights that are not manufactured, examples are Sun, lightning, natural fires, volcanoes and phosphorescence.
- Artificial source of light
  are those that are manufactured, examples are man-made fires, light bulbs, fluorescent tubes and television screens.
- Light travels at 300 000 kilometres per second in a gas. When light travels through a liquid, it slows down. When light travels through a solid, it is slowed down further.
- Both the particle theory and the wave theory are needed to explain the behaviour of light. This is known as the dual nature of light.




The figure above shows the electromagnetic spectrum.

- Light and Optics
- Rays and shadows
- Reflection of light
- The refraction of light
- Total internal Reflection
- Converging lenses
- Optical instruments
- The eye
- Colour
- Light in the night sky

| Topic 5: Electrical Current and Circuits | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.20** Construct one or more electrostatic apparatus and explain how they function using the particle model of electricity.<br>**10.3.3.21** Investigate and describe qualitatively the relationship among current, voltage (electric potential difference), and resistance in a simple electric circuit.<br>**10.3.3.22** Define voltage (electric potential difference) as the energy per unit charge between two points along a conductor and solve related problems. Include: V= E/Q |
| **Key question** | 1. Why is it important for us to study electric currents and circuits?<br>2. What are some types of circuits you know of from prior knowledge? |
| **Learning objectives** | By the end of this topic, students can:<br>Describe electrostatic apparatus and explain how they function using the particle model of electricity.<br>Investigate qualitatively the relationship amongst current, voltage and resistance. |
| **Vocabulary** | Electrons, electricity, current, voltage, ohms, |
| **Knowledge** | Theory and practices of electric current and circuits |
| **Skills** | Analyse, discuss and compare electric currents and circuits. |
| **Attitudes and values** | Appreciate the usefulness of electricity. |
| **Teaching and Learning strategies** | Research and discuss.<br>Project and presentations. |
| **Assessment** | Construct either a parallel or series circuit model and present its functions. |
| **Materials** | Wires, dry cells, bulbs, switch |

## Content Background

**Under Electricity**

- Types of electricity
  - Static electricity
  - Electric cells
  - Conductors and Insulators
  - Safety with electricity
  - Fuses and Circuit Breakers
  - Three-pin plugs and earth wires
  - Circuits-Series and parallel circuits
  - Short circuits
- Uses of electricity
  - The heating effect
  - The lighting effect
  - The magnetic effect
  - The electric motor
- Household electricity
  - Electric power and costing
  - Power of appliances
  - reading the meter
  - Energy conservation
- Generating electricity
  - The magnetic method
  - The light method
  - The heating method
  - National Production of electricity
  - Transmission of Electricity

| Topic 6: Magnets and Electric Current | |
|---|---|
| **Content standard** | Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy. |
| **Benchmark** | **10.3.3.19** Demonstrate and explain the like nature of electrostatics and current electricity.<br>**10.3.3.20** Construct one or more electrostatic apparatus and explain how they function using the particle model of electricity. |
| **Key questions** | 1. What are magnets?<br>2. What produces electric current? |
| **Learning objectives** | By the end of this topic, students can:<br>• Investigate and describe the properties of magnet and electromagnets |
| **Vocabulary** | Electromagnetism, magnets, magnetic field |
| **Knowledge** | Specialise knowledge on the magnets and current |
| **Skills** | Analysis and discovering magnets and their production of electricity. |
| **Attitudes and values** | Appreciate the use of magnets in electricity production. |
| **Teaching and Learning strategies** | Research and discussion<br>Projects and presentation |
| **Assessment** | Construct an AD or DC motor and explain its functions. |
| **Materials** | Wires, motor, dry cell, power supply, switch |

## Content Background

### Moving Charges Create Magnetic Fields

In the last section we learned that a magnetic field affects moving charges. By Newton's third law, the moving charges must exert an equal and opposite force on whatever produced the BB field. In other words, the moving charge must create its own BB field! By using Newton's third law we can complete the description of the indirect model we started earlier:

Moving charges –g–––––creates fieldB––g–––––exerts force on

Moving charges(1)(1)Moving charges →creates fieldB→exerts force onMoving charges

As we learned in Physics 7B moving charges constitute an electric current; a concept that is particular useful if we have a steady flow of charge. Considering a separate charge qq, the indirect model becomes:

Current –→––––––creates fieldB–→––––––––exerts force onMoving charge q(2 (2)

Current →creates field B→e xerts force onMoving charge q

### Electromagnetism: A History

While we have worked this out, it is far from clear what currents and moving charges have to do with anything related to the fridge magnets or bar magnets that make magnetism familiar to us. In essence we have cheated: the ideas of how a magnetic field affects moving charges were not known until the mid-1800s. Before that, the only thing known about magnetism was that some materials can produce magnetic fields and these attract (or repel) certain kinds of other similar materials, and that the Earth had its own magnetic field which aligns these magnetic materials. These facts were known to the Greeks as early as 600 BC. The question of why certain materials where magnetic while others did not appear to be, and what phenomenon created these magnetic fields was not addressed until 1820.

In 1820, Dutch physicist Hans Christian Ørsted had set up an experiment to show that large electric currents could be used to heat a wire. While demonstrating this to a group of students in his house, he noticed that a compass on his bookshelf changed direction whenever his "kettle" was switched on. After months of investigation, Ørsted concluded that *an electric current could create a magnetic field*. This was big news at the time, because prior to this only magnetic fields were known to affect other magnetic materials. This was a watershed moment in the history of science, as it was the first link between electric and magnetic phenomena. Originally we experience these as two distinct forces, two distinct fields. Ørsted's finding was the first step on the road that led humankind to find that these apparently dissimilar phenomena were in fact linked. This unification of seemingly disconnected ideas is still at the core of fundamental research: much hope is placed on possibly unifying *all* forces in nature.

**What is a Magnet?**

The finding that electricity and magnetism are linked caused a huge revolution in science, but we now want to return to our question of what makes a magnet a magnet. Ørsted showed us that electric currents created a magnetic field, but where are the currents in a magnetized piece of Iron? People could not answer this question until the late 1800s, and even then they were met with skepticism. The answer relied on the existence of atoms: in a nutshell, the origins of magnetism are found to be the electric currents produced by the electrons orbiting (i.e. making a current loop) atomic nuclei.

The magnetism of certain materials also depends on spin orientation. **Spin** endows the electrons with an intrinsic angular momentum. This "intrinsic spin" can only have two possible values (you might have heard that an electron can be "spin up" or "spin down" in your physics or chemistry classes). Spin is a purely quantum mechanical phenomenon, but for the purposes of thinking about magnetism in our current discussion, consider spin an additional way to produce a loop of current (the smallest one you can imagine!)

The fact that atoms exist is something we now take for granted, but most scientists thought of it as ludicrous until 1905 (due in large part to a separate contribution by Einstein)! They reasoned that all things in they saw in motion lost energy due to friction, and the idea of electrons perpetually moving around in atoms seemed absurd to them.

**Only Some Materials Are Magnetic**

To summarize, all our experiments point to the following finding: to get a magnetic field, we need a net motion of charge. How does this idea explain magnetism in materials? Imagine helium, an atom with two electrons. Now if these electrons go around in opposite directions, the currents they produce will be opposite to each other. The magnetic field of one current loop will cancel the magnetic field of the other, leading to no net magnetic field. The spin also affects the magnetic field, and if the spins are pointed in the same direction (both up or both down) the field gets stronger, while if they are aligned in opposite directions the field gets weaker. In helium, the spins of the two electrons are paired up-down, so helium would not be very magnetic. As it turns out, helium is an "anti-magnet" and tries to stop any magnetic field going through it. This effect is called diamagnetism and is a manifestation of Lenz's law which we have not covered yet.

However, there are many materials whose atoms have an odd number of electrons but who don't exhibit magnetism, how can that be? So far we have discussed the effects of the magnetic field on individual atoms; we need to consider the possibilities that these atoms are also interacting strongly with each other. Since a material is made up of □1023□1023 atoms, tiny effects, like the ones between atoms, can become large if each atom contributes to it. Highly magnetic materials are generally metals, because metals have many outer electrons that act as if they're "free," and can interact strongly with external fields and with each other.

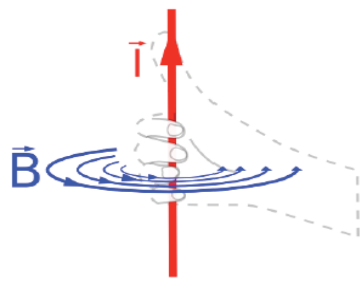
**Ampère's Law**
We see that magnetism boils down to moving charges affecting other moving charges. It is no surprise that an explanation of the phenomena of bar magnets took so long; it required a serendipitous observation of how two superficially unlike phenomena (electricity and magnetism) affected one another *and* the atomic model. We have already studied how a magnetic field affects a moving charge. Now we turn to the quantitative question of how, exactly, a current produces a magnetic field.

**Field Produced by a Long, Straight Wire**
We will first study a simple test case: a long straight wire carrying a current. We want to understand the magnetic field produced by this wire, i.e. how strong it is in magnitude, where it points (recall it is a vector), and how does it vary with position. In other words, we want to map the BB field.

We will retrace some of Ørsted's steps. He showed that a current-carrying conductor produces a magnetic field. A simple way to demonstrate this is to place several compass needles in a horizontal plane (for example, the surface of a table) near a long wire placed vertically (running up and down through the table surface). Let's assume the current direction to be coming from the bottom and going toward the top of the table. When there is no current in the wire, all needles point in the same direction (magnetic north). As soon as current starts flowing in the wire, all needles will deflect. We have produced a magnetic field!

The first thing that one notices when doing this experiment, is that the needles orient themselves in a recognizable pattern; if we draw a circle on the table with the wire at the center and we place the compasses along the circle, we will notice that all the compass needles will orient themselves tangential to the circle. In other words, the field lines for BB from a long straight wire at a distance rr from the wire will have the shape of concentric circles of radius rr. For our experiment with the current coming out of the table, we find that the BB field direction is counterclockwise along the circles. If we flip the direction of the current, the compass needles will still point tangent to the circle, but now their north poles point in a clockwise direction.

Right-Hand Rule
This observation for the direction of the BB field can be summarized with the following convenient rule, right-hand-rule #1 (RHR #1): Point the thumb of your right hand along a wire in the direction of the conventional (positive) current. Your fingers will now curve naturally in the direction of the magnetic field.




What can we infer about the magnitude of the magnetic field? By symmetry, the magnetic field should have the same magnitude everywhere along the circle. Why is this? Every point along the circle is equidistant from the wire, and have the same distance rr from the wire. Likewise, if the wire is infinitely long, we could chose to place a horizontal plane (with compasses on it) anywhere along the wire. Moving this horizontal plane up or down along the wire, should also have no effect in our results. To be mathematically precise, we can set the plane of the wire to be the x-y plane, and the direction along the wire to be the z-axis. We see that, by symmetry, the magnetic field does not depend on the z coordinate.

## Unit 10.9: Our Earth

The geology of Papua New Guinea is very unique in that most of the natural processes that are responsible for shaping the planet Earth are found here. From the study of the continental and oceanic crusts, the processes of oceanic and seafloor spreading underneath the oceans, students will be able to recognise and identify the structures such as mid-ocean ridges, trenches and transforms, and the magnetic anomalies which are all indicators of the past, present, and future evolution of the planet.

Students identify some common minerals, describe the origin of rocks and give examples of common rock types and how they are used. They use a map showing the location of earthquakes and volcanoes to identify the position of tectonic plate margins and describe the processes happening. Students understand how the geological occurrence and properties of an ore are related to how it is mined. They recognise the impact of mining on the physical environment and suggest ways in which the area can be rehabilitated: for example, students explain why topsoil is removed and stored during bauxite mining and replaced to begin rehabilitation.

Students recognise that humans have made use of the earth's materials according to properties of these materials: for example, they might describe how wet sand makes better sandcastles than does dry sand; explain why adding humus to a sandy soil makes plants grow better; suggest why chert is preferred to sandstone for the manufacture of stone tools; or discuss how the nature and variety of archaeological artefacts can be used to deduce how past civilisations lived and worked in their environment.

Students understand that the earth's resources are finite and argue the importance of conserving and replacing them: for example, they identify and take steps to remedy water wastage in their home or school by detecting leaky taps, monitoring the placement of sprinklers, describing water consumption in their community (taking into account seasonal variation and the nature of the water supply) or creating an effective plan to monitor community water use.

Students understand that the earth is composed of materials that are altered by forces within it and on its surface. They describe the processes of weathering, erosion and tides and how such physical processes affect the landscape. They give examples of erosion in their local area, such as in river beds, sand dunes or salt lakes, and evaluate the success of steps taken to remedy its effects.

## Topic 1: The Rock Cycle

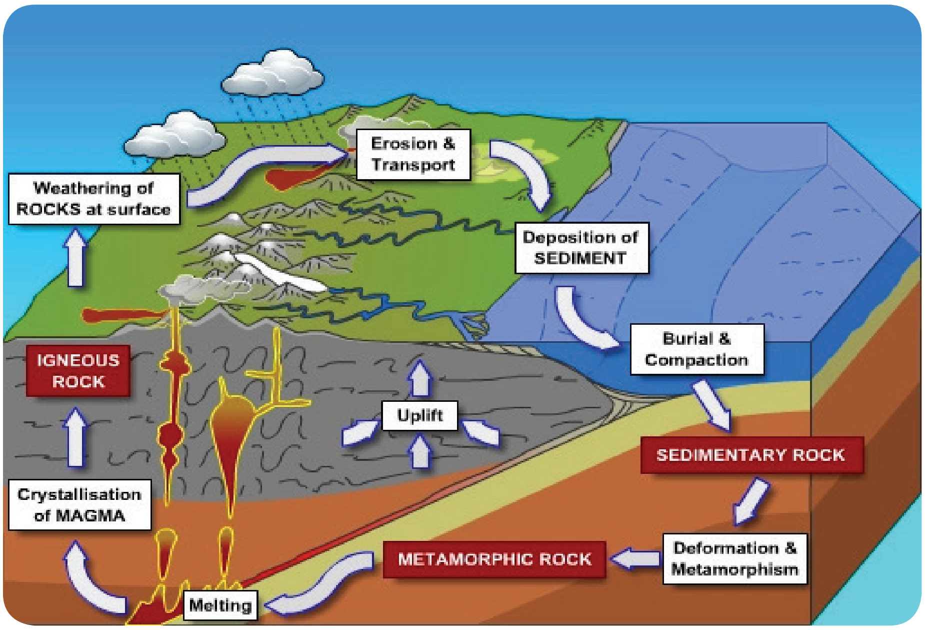
| | |
|---|---|
| **Content standard** | Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space. |
| **Benchmark** | **10.4.4.1** Investigate the processes of weathering, erosion, deposition, and lithification or compaction that shape the surface of the Earth. |
| **Key question** | How are rocks formed? |
| **Learning objectives** | By the end of the topic, the students will be able to;<br>• Analyse the process of rock cycle |
| **Vocabulary** | Rock cycle, igneous, sedimentary, metamorphic |
| **Knowledge** | Rock cycle |
| **Skills** | Comparing, analysing, visualising |
| **Attitudes and values** | open minded, with desire to learn, be responsible |
| **Teaching and Learning strategies** | Teachers prepare information (including pictures) and ask questions on rock cycle. Teachers can show videos related to the rock cycle while the students use the information provided to answer the questions about the topic. |
| **Assessment** | 1. Develop a rock cycle chart with diagrams and the labels |
| **Materials** | Chart with the diagram of rock cycle, sample of the 3 types of rocks. |

### Content Background

Rocks are the most common material on Earth. They are naturally occurring aggregates of one or more minerals.

Rock divisions occur in three major families based on how they formed: igneous, sedimentary, and metamorphic. Each group contains a collection of rock types that differ from each other on the basis of the size, shape, and arrangement of mineral grains.

The rock cycle is an illustration that is used to explain how the three rock types are related to each other and how Earth processes change a rock from one type to another through geologic time. Plate tectonic movement is responsible for the recycling of rock materials and is the driving force of the rock cycle.



### Transition to igneous rock

When rocks are pushed deep under the Earth's surface, they may melt into magma. If the conditions no longer exist for the magma to stay in its liquid state, it cools and solidifies into an igneous rock. A rock that cools within the Earth is called intrusive or plutonic and cools very slowly, producing a coarse-grained texture such as the rock granite. As a result of volcanic activity, magma (which is called lava when it reaches Earth's surface) may cool very rapidly while being on the Earth's surface exposed to the atmosphere and are called extrusive or volcanic rocks. These rocks are fine-grained and sometimes cool so rapidly that no crystals can form and result in a natural glass, such as obsidian; however the most common fine-grained rock would be known as basalt. Any of the three main types of rocks (igneous, sedimentary, and metamorphic rocks) can melt into magma and cool into igneous rocks.

### Transition to metamorphic rock

Rocks exposed to high temperatures and pressures can be changed physically or chemically to form a different rock, called metamorphic. Regional metamorphism refers to the effects on large masses of rocks over a wide area, typically associated with mountain building events within orogenic belts. These rocks commonly exhibit distinct bands of differing mineralogy and colors, called foliation. Another main type of metamorphism is caused when a body of rock comes into contact with an igneous intrusion that heats up this surrounding country rock. This contact metamorphism results in a rock that is altered and re-crystallized by the extreme heat of the magma and/or by the addition of fluids from the magma that add chemicals to the surrounding rock (metasomatism). Any pre-existing type of rock can be modified by the processes of metamorphism.

### Transition to sedimentary rock

Rocks exposed to the atmosphere are variably unstable and subject to the processes of weathering and erosion. Weathering and erosion break the original rock down into smaller fragments and carry away dissolved material. This fragmented material accumulates and is buried by additional material. While an individual grain of sand is still a member of the class of rock it was formed from, a rock made up of such grains fused together is sedimentary. Sedimentary rocks can be formed from the lithification of these buried smaller fragments (clastic sedimentary rock), the accumulation and lithification of material generated by living organisms (biogenic sedimentary rock - fossils), or lithification of chemically precipitated material from a mineral bearing solution due to evaporation (precipitate sedimentary rock). Clastic rocks can be formed from fragments broken apart from larger rocks of any type, due to processes such as erosion or from organic material, like plant remains. Biogenic and precipitate rocks form from the deposition of minerals from chemicals dissolved from all other rock types.

## Topic 2: Minerals and Fossil Fuel

| | |
|---|---|
| **Content standard** | Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space. |
| **Benchmark** | **10.4.4.3** Distinguish between minerals and rocks. |
| **Key questions** | 1. What are the properties of minerals?<br>2. What are the different types of fossil fuels? |
| **Learning objectives** | By the end of the lesson, the students will be able to;<br>• Explain the properties of minerals<br>• Analyse the different types of fossil fuels |
| **Vocabulary** | Minerals, fossil fuel |
| **Knowledge** | • Properties of minerals<br>• Types of fossil fuel |
| **Skills** | analysing, grouping and classifying, comparing |
| **Attitudes and values** | Open-minded, appreciative, willing to learn |
| **Teaching and Learning strategies** | Teachers prepare information (including pictures) and ask questions on minerals and fossil fuel while students answer the questions on the information provided based on the topic. |
| **Assessment** | 1. Research on how minerals can be identified using the physical properties according to Moh's Scale |
| **Materials** | Rock samples, pictures with information on minerals and fossil fuel,chart of Moli's seal |

### Content Background

A mineral is defined in part by a specific chemical composition. In theory, therefore, it is always easy to identify a mineral, if you can determine the chemical composition with a mass spectrometer like the Mars rovers. In reality, however, even if you are looking at rocks on Earth, determining the exact chemical composition of a substance involves significant time preparing the sample and sophisticated laboratory equipment (and often significant money). Luckily, it is usually unnecessary to go to such lengths, because there are much easier ways that require little more than a magnifying lens and a penknife.

**Identifying minerals by physical properties**

The most common minerals in Earth's crust can often be identified in the field using basic physical properties such as color, shape, and hardness. The context of a mineral is important, too – some minerals can form under the same conditions, so you are likely to find them in the same rock, while others form under very different conditions and will never occur in the same rock. For this reason, context (the other surrounding minerals and type of rock) can often be used to rule out minerals that have similar color, for example. Although there are many thousands of named minerals, only a dozen or so are common in Earth's crust. Testing a few physical properties therefore means that you can identify about 90% of what you are likely to encounter in the field.

Because the physical properties of a mineral are determined by its chemical composition and internal atomic structure, they can be used diagnostically, the way a runny nose and sore throat can be used to diagnose a cold. There are many physical properties of minerals that are testable with varying degrees of ease, including color, crystal form (or shape), hardness, luster (or shine), density, and cleavage or fracture (how the mineral breaks). In addition, many minerals have unique properties, such as radioactivity, fluorescence under black light, or reaction to acid.

https://www.visionlearning.com/en/library/Earth-Science/6/Properties-of-Minerals/130

**Fossil fuel** is a general term for buried combustible geologic deposits of organic materials, formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils by exposure to heat and pressure in the earth's crust over hundreds of millions of years.

Fossil fuels include **coal**, **petroleum**, **natural gas**, **oil shales**, bitumens, tar sands, and heavy oils. All contain carbon and were formed as a result of geologic processes acting on the remains of organic matter produced by photosynthesis, a process that began in the Archean Eon (4.0 billion to 2.5 billion years ago).

**Fossil fuel** is a generic term for non-renewable energy sources such as coal, coal products, natural gas, derived gas, crude oil, petroleum products and non-renewable wastes. These fuels originate from plants and animals that existed in the geological past (for example, millions of years ago). Fossil fuels can be also made by industrial processes from other fossil fuels (for example in the oil refinery, crude oil is transformed into motor gasoline).

For decades fossil fuels satisfy most of the human energy requirements. Fossil fuels are carbon-based and their combustion results in the release of carbon into the Earth's atmosphere (carbon that was stored hundreds of millions years ago). It is estimated that roughly 80% of all manmade $CO_2$ and green-house gas emissions originate from fossil fuels combustion.

In energy statistics, fossil fuels cover:

- Solid fossil fuels (aka coal)
  - Hard coal
    - Anthracite
    - Coking coal
    - Other Bituminous coal
  - Brown coal
    - Sub-bituminous coal
    - Lignite
  - Coal products
    - Patent fuel
    - Coke oven coke
    - Gas coke
    - Coal tar
    - Brown coal briquettes
- Manufactured gases
  - Coke oven gas
  - Blast furnace gas
  - Gas works gas
  - Other recovered gases
- Peat and peat products
  - Peat
  - Peat products
- Oil shale and oil sands
- Oil and petroleum products (excludi
  - Crude oil, NGL, refinery feedsto hydrocarbons (excluding biofuel
    - Crude oil
    - Natural gas liquids
    - Refinery feedstocks
    - Additives and oxygenates (e
    - Other hydrocarbons

- Oil products (excluding biofuel portion)
    - Refinery gas
    - Ethane
    - Liquefied petroleum gases
    - Motor gasoline (excluding biofuel portion)
    - Aviation gasoline
    - Gasoline-type jet fuel
    - Kerosene-type jet fuel (excluding biofuel portion)
    - Other kerosene
    - Naphtha
    - Gas oil and diesel oil (excluding biofuel portion)
    - Fuel oil
    - White spirit and special boiling point industrial spirits
    - Lubricants
    - Bitumen
    - Petroleum coke
    - Paraffin waxes
    - Other oil products
- Natural gas
- Non-renewable waste
  - Industrial waste (non-renewable)
  - Non-renewable municipal waste

| Topic 3: Natural Hazards | |
|---|---|
| **Content standard** | Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space. |
| **Benchmark** | **10.4.4.5** Identify and investigate local examples of how living things affect the non-living environment and vice versa.<br>**10.4.4.6** Evaluate human impact on local and regional |
| **Key questions** | 1. What are natural hazards?<br>2. What causes natural hazards? |
| **Learning objectives** | By the end of the lesson, the students will be able to;<br>• Explain natural hazards and the causes of natural hazards<br>• Identify and analyse the causes of natural hazards |
| **Vocabulary** | • Hazards, natural hazard, geological hazards, hydrological hazards, meteorological hazards, and biological hazards |
| **Knowledge** | • Natural hazards |
| **Skills** | • Making inference, visualising, modelling, analysing, relating |
| **Attitudes and values** | Respect for the environment, appreciate, desire to learn |
| **Teaching and Learning strategies** | Teachers prepare information (including pictures) and ask questions on natural hazards while students answer the questions on the information provided based on the topic. |
| **Assessment** | 1. Research and classify natural hazards as geological hazards, hydrological hazards, meteorological hazards and biological hazards. |
| **Materials** | Information with pictures of natural hazards, PNG map showing areas of natural hazards |

## Content Background

What is a Natural Hazard?
"Hazard always arises from the interplay of social and biological and physical systems; disasters are generated as much or more by human actions as by physical events." (Geographer Gilbert F. White, the "father of floodplain management")

A hazard is distinguished from an extreme event and a disaster. A natural hazard is an extreme event that occurs naturally and causes harm to humans – or to other things that we care about, though usually the focus is on humans (which, we might note, are anthropocentric). An extreme event is simply an unusual event; it does not necessarily cause harm. Note that many hazards have both natural and artificial components. Because hazards are threats of harm mainly to human systems, human activities play a large role in how severe a hazard is. For example, when large numbers of people crowd into floodplains and low-lying areas, they are putting themselves in harm's way, increasing the severity of potential floods. Many major cities are built in coastal areas. These cities face the threat of rising sea levels, a hazard being caused by global climate change. In short, the severity of the impacts from a natural hazard depends on both the physical nature of the extreme event and on the details of human development decisions.

Natural hazards can be classified into several broad categories: geological hazards, hydrological hazards, meteorological hazards, and biological hazards. Geological hazards are hazards driven by geological (i.e., Earth) processes, in particular, plate tectonics. This includes earthquakes and volcanic eruptions.

What causes natural disasters?

| Topic 4: Causes and Effects of Plate Movements | |
|---|---|
| **Content standard** | Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space. |
| **Benchmark** | **9.4.4.7** Deconstruct and explain the plate tectonics theory. |
| **Key question** | 1. What are the causes of plate movements?<br>2. What are the effects of plate movements? |
| **Learning objectives** | By the end of the topic, the students will be able to;<br>• Identify and analyse the plate movements<br>• Analyse the effects of plate movements. |
| **Vocabulary** | Tectonic plates, plate boundaries, continental drift |
| **Knowledge** | • Causes of plate movements<br>• Effects of plate movements |
| **Skills** | • making inferences, analysing, modelling |
| **Attitudes and values** | • Open-minded, appreciative, critical |
| **Teaching and Learning strategies** | Teachers prepare information (including pictures) and ask questions on the causes and effects of plate movements. Teachers can take students out for an excursion to a nearby weather station or show videos related to the topic. |
| **Assessment** | 1. Model the plate movement and demonstrate the movement of the plates (rock rafts) |
| **Materials** | Charts with diagrams of plate tectonic, model of the earth. |

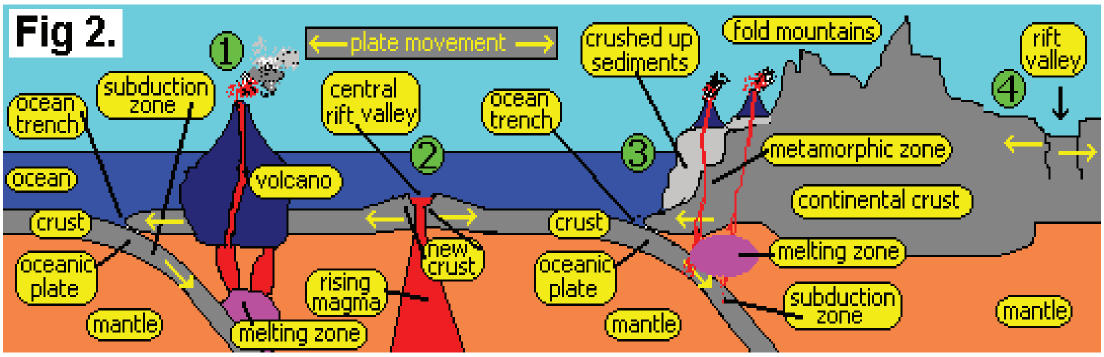
## Content Background

**PLATE TECTONICS THEORY:**

The Earth's lithosphere (the crust and the upper part of the mantle) is cracked into a number of large pieces called tectonic plates, you can think of them as giant rock rafts floating on the 'plastic' mantle. These plates (like big rock rafts) are less dense than the mantle and so float on it and constantly move at relative speeds of a few centimetres per year as a result of convection currents within the Earth's mantle. The convection currents are driven by heat released by natural radioactive processes in the mantle. This is what is meant by 'Continental Drift'. Earthquakes and/or volcanic eruptions occur at the plate boundaries between tectonic plates exemplified by the volcanic 'Ring of Fire' in the Pacific Ocean and the earthquake zone of the San Andreas Fault on the west coast of North America. This geologically violent activity happens when plates collide, move away from each other and when one plates sub-ducts below another.

***Explanation of Plate Tectonics and subduction***

- The Earth's lithosphere (the crust and the upper part of the mantle) is cracked into a number of large pieces called tectonic plates.
- These plates are constantly moving at relative speeds of a few centimetres per year as a result of convection currents within the Earth's mantle driven by heat released by natural radioactive processes in the mantle.
- This is what is meant by 'Continental Drift'. Earthquakes and/or volcanic eruptions occur at the boundaries between tectonic plates exemplified by the volcanic 'Ring of Fire' in the Pacific Ocean and the earthquake zone of the San Andreas Fault on the west coast of North America.
- So some parts of the world are much more susceptible to volcanic and earthquake activity and very little of these effects can be predicted!

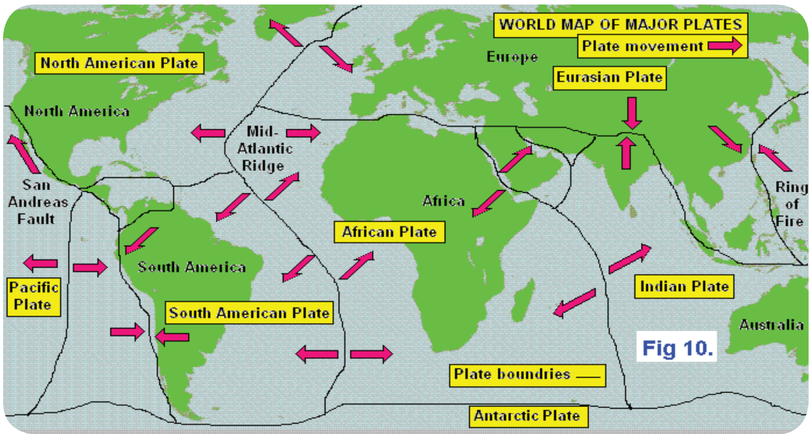



Source: [http://www.docbrown.info/page21/GeoChangesANS09.htm](http://www.docbrown.info/page21/GeoChangesANS09.htm)

a) When plates move apart: New crust is formed mainly at mid-ocean ridges where magma breaks through huge fractures in the crust. ((2) in Fig 2. above) This is known as sea floor spreading and is happening along oceanic ridges, including the mid-Atlantic ridge. This causes cracks through which more molten magma material from deep below the lithosphere can push through producing new rock. The magma from theses chains of linked undersea volcanoes (or just long gashes of hundreds of kilometres!) rapidly cools to form basalt type rocks of the new crust spreading out on either side. (see also evidence for this mechanism) Sometimes a long central rift valley forms (4). All in all, what is described below is the detail of the ultimate rock recycling machine!

(b) When plates collide [more in 9(c)]: Crust material is removed from the tectonic plates whenever two plates collide head on because one plate descends into the subduction zone to be melted and combined with the mantle material ((1) oceanic-oceanic plates meeting (e.g. Pacific Ring of Fire) and (3) oceanic-continental plates meeting (e.g. Andes Mountains) in Fig 2. above). One plate descends into a deep ocean trench, and mud and sand pour into these trenches and at (3) can end up as bands of metamorphic rock in the 'fold' mountains - see 9(c)

**World map of major plates of the Earth's crust and some regions of specific geological activity**




Source: [http://www.docbrown.info/page21/GeoChangesANS09.htm](http://www.docbrown.info/page21/GeoChangesANS09.htm)

# Unit 10.10 Weather and Climate

| Topic 1: Global Weather Systems | |
|---|---|
| **Content standard** | Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space. |
| **Benchmark** | **10.4.4.8** Relate cloud types to weather.<br>**10.4.4.9** Investigate the movement of air.<br>**10.4.4.10** Explain the formation of weather fronts and how they behave. |
| **Key question** | • What are global weather systems?<br>• How do global patterns in the atmosphere affect the local weather patterns? |
| **Learning objectives** | By the end of the topic, the students will be able to;<br>• Define and explain weather systems<br>• Analyse how global patterns in the atmosphere affect the local weather pattern |
| **Vocabulary** | • Weather pattern, air mass, front, jet stream, coriolis effect |
| **Knowledge** | • Global weather systems<br>• Weather patterns |
| **Skills** | Making inference, comparing and contrasting, analysing |
| **Attitudes and values** | Open-minded, appreciative |
| **Teaching and Learning strategies** | Teachers prepare information (including pictures) and ask questions global weather systems. Teachers can take students out for an excursion to a nearby weather station or show videos related to the weather systems while students will use the information provided to answer the questions on the topic. |
| **Assessment** | 1. Research on how global weather is monitored by weather stations. |
| **Materials** | Pictures of global weather patterns |

## Content Background

**'Global weather systems'** explains that air masses can be classified into categories based on the humidity and temperature of their source region: arctic or antarctic continental, polar continental, tropical continental, arctic maritime, polar maritime, tropical maritime, and equatorial maritime.

The local weather that impacts our daily lives results from large global patterns in the atmosphere caused by the interactions of solar radiation, Earth's large ocean, diverse landscapes, and motion in space.

### Global winds

Earth's orbit around the sun and its rotation on a tilted axis causes some parts of Earth to receive more solar radiation than others. This uneven heating produces global circulation patterns.offsite link For example, the abundance of energy reaching the equator produces hot humid air that rises high into the atmosphere. A low pressure area forms at the surface and a region of clouds forms at altitude. The air eventually stops rising and spreads north and south towards the Earth's poles. About 2000 miles from the equator, the air falls back to Earth's surface blowing towards the pole and back to the equator. Six of these large convection currents cover the Earth from pole to pole.

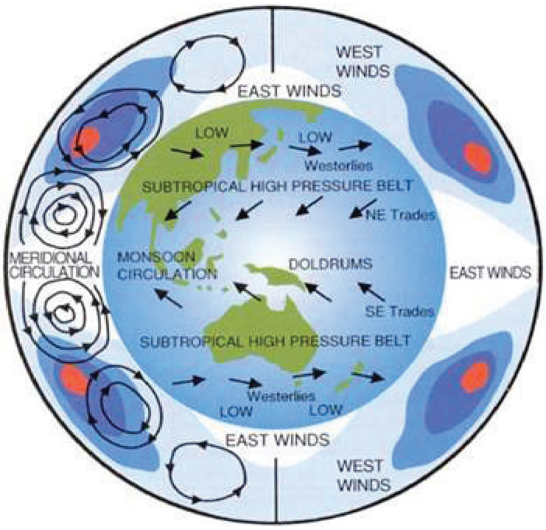



Figure 1: Global wind patte

**Air masses**

These global wind patterns drive large bodies of air called air masses. Air masses are thousands of feet thick and extend across large areas of the Earth. The location over which an air mass forms will determine its characteristics. For example, air over the tropical ocean becomes exceptionally hot and humid. Air over a high latitude continent may become cold and dry. You have probably noticed the temperature rapidly dropping on a nice warm day as a cold air mass pushed a warm one out the way.

**Fronts**

The location where two air masses meet is called a front. They can be indirectly observed using current weather maps, which can be used to track them as the move across the Earth. Cold fronts, generally shown in blue, occur where a cold air mass is replacing a warm air mass. Warm fronts, shown in red, occur where warm air replaces cold air.

**Jet streams**

The local weather conditions that we experience at the Earth's surface are related to these air masses and fronts. However the environment far above us impacts their movement. High in the atmosphere, narrow bands of strong wind, such as the jet streams, steer weather systems and transfer heat and moisture around the globe.

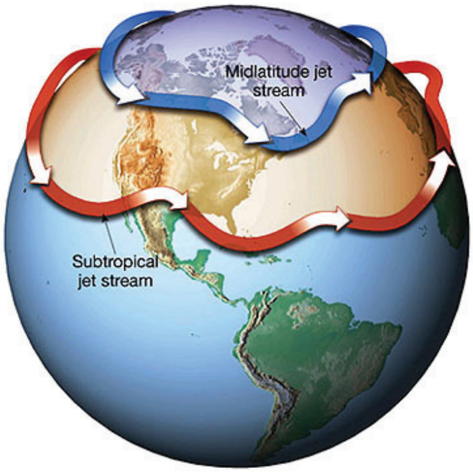



Figure 2: Jet Streams

**Coriolis effect**

As they travel across the Earth, air masses and global winds do not move in straight lines. Similar to a person trying to walk straight across a spinning Merry-Go-Round, winds get deflected from a straight-line path as they blow across the rotating Earth. In the Northern Hemisphere air veers to the right and in the Southern Hemisphere to the left. This motion can result in large circulating weather systems, as air blows away from or into a high or low pressureoffsite link area. Hurricanes and nor'easters are examples of these cyclonic systems.

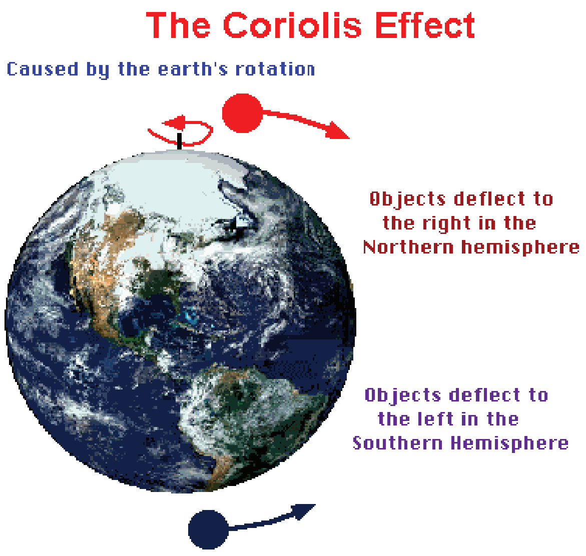



Figure 3. Coriolis Effect
Source: https://www.noaa.gov/education/resource-collections/weather-atmosphere/weather-systems-patterns

## Unit 10.11: Space Science

| Topic 1: The Solar System and Beyond | |
|---|---|
| **Content standard** | Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space. |
| **Benchmark** | **10.4.4.21** Investigate and understand scientific concepts related to the origin and evolution of the universe.<br>**10.4.4.22** Describe cosmology including the Big Bang theory.<br>**10.4.4.23** Explore and explain the origin and evolutionof stars, star systems, and galaxies. |
| **Key questions** | 1. How did the solar system form?<br>2. Why is it called a solar system?<br>3. How is the solar system structured? |
| **Learning objectives** | By the end of the topic, the students will be able to;<br>• Investigate the formation of the solar system<br>• Analyse the structure of the solar system |
| **Vocabulary** | • Solar system, galaxy, stars, moon |
| **Knowledge** | • Solar system |
| **Skills** | • Making generalisation, making inference, visualising, analysing, modelling |
| **Attitudes and values** | Participatory, appreciative, with desire to learn, open-minded |
| **Teaching and Learning strategies** | Teachers prepare information (including pictures) and ask questions on the solar systems while students will use the information provided to answer questions about the topic. |
| **Assessment** | 1. Model the structure of the solar system |
| **Materials** | Chart containing the diagrams/pictures of the solar system including the eight planets |

### Content Background

Why Is It Called The “Solar” System?

There are many planetary systems like ours in the universe, with planets orbiting a host star. Our planetary system is named the “solar” system because our Sun is named Sol, after the Latin word for Sun, “solis,” and anything related to the Sun we call “solar.”

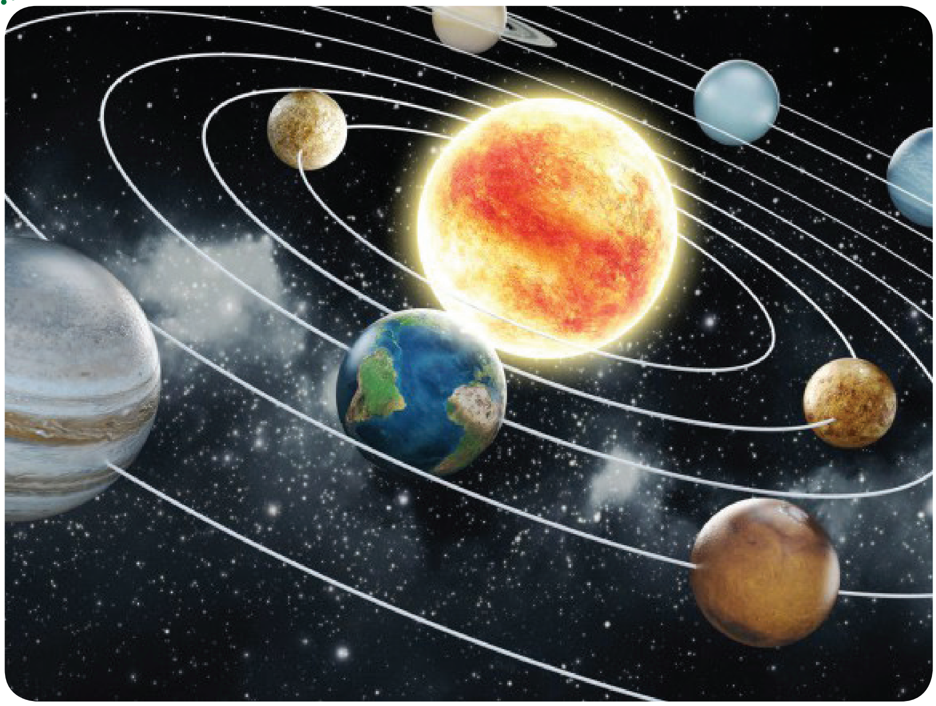


Figure 1. Solar System

Our planetary system is located in an outer spiral arm of the Milky Way galaxy.

Our solar system consists of our star, the Sun, and everything bound to it by gravity — the planets Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, dwarf planets such as Pluto, dozens of moons and millions of asteroids, comets and meteoroids. Beyond our own solar system, we have discovered thousands of planetary systems orbiting other stars in the Milky Way.

**Size and Distance**

Our solar system extends much farther than the eight planets that orbit the Sun. The solar system also includes the Kuiper Belt that lies past Neptune's orbit. This is a sparsely occupied ring of icy bodies, almost all smaller than the most popular Kuiper Belt Object, dwarf planet Pluto.

And beyond the fringes of the Kuiper belt is the Oort Cloud. This giant spherical shell surrounds our solar system. It has never been directly observed, but its existence is predicted based on mathematical models and observations of comets that likely originate there.

The Oort Cloud is made of icy pieces of space debris the sizes of mountains and sometimes larger, orbiting our Sun as far as 1.6 light years away. This shell of material is thick, extending from 5,000 astronomical units to 100,000 astronomical units. One astronomical unit (or AU) is the distance from the Sun to Earth, or about 93 million miles (150 million kilometers). The Oort Cloud is the boundary of the Sun's gravitational influence, where orbiting objects can turn around and return closer to our Sun.

The Sun's heliosphere doesn't extend quite as far. The heliosphere is the bubble created by the solar wind—a stream of electrically charged gas blowing outward from the Sun in all directions. The boundary where the solar wind is abruptly slowed by pressure from interstellar gases is called the termination shock. This edge occurs between 80-100 astronomical units.

Two NASA spacecraft, launched in 1977, have crossed the termination shock: Voyager 1 in 2004 and Voyager 2 in 2007. But it will be many thousands of years before the two Voyagers exit the Oort Cloud.

**Formation**

Our solar system formed about 4.5 billion years ago from a dense cloud of interstellar gas and dust. The cloud collapsed, possibly due to the shockwave of a nearby exploding star, called a supernova. When this dust cloud collapsed, it formed a solar nebula—a spinning, swirling disk of material. At the center, gravity pulled more and more material in. Eventually the pressure in the core was so great that hydrogen atoms began to combine and form helium, releasing a tremendous amount of energy. With that, our Sun was born, and it eventually amassed more than 99 percent of the available matter.

Matter farther out in the disk was also clumping together. These clumps smashed into one another, forming larger and larger objects. Some of them grew big enough for their gravity to shape them into spheres, becoming planets, dwarf planets and large moons. In other cases, planets did not form: the asteroid belt is made of bits and pieces of the early solar system that could never quite come together into a planet. Other smaller leftover pieces became asteroids, comets, meteoroids, and small, irregular moons.

**Structure**

The order and arrangement of the planets and other bodies in our solar system is due to the way the solar system formed. Nearest the Sun, only rocky material could withstand the heat when the solar system was young. For this reason, the first four planets—Mercury, Venus, Earth and Mars—are terrestrial planets. They're small with solid, rocky surfaces. Meanwhile, materials we are used to seeing as ice, liquid or gas settled in the outer regions of the young solar system. Gravity pulled these materials together, and that is where we find gas giants Jupiter and Saturn and ice giants Uranus and Neptune.

**Potential for Life**

Our solar system is the only place we know of that harbors life, but the farther we explore the more we find potential for life in other places. Both Jupiter's moon Europa and Saturn's moon Enceladus have global saltwater oceans under thick, icy shells.

**Moons**

There are more than 150 known moons in our solar system and several more awaiting confirmation of discovery. Of the eight planets, Mercury and Venus are the only ones with no moons. The giant planets grab the most moons. Jupiter and Saturn have long lead our solar system's moon counts. In some ways, the swarms of moons around these worlds resemble mini versions of our solar system. Pluto, smaller than our own moon, has five moons in its orbit, including the Charon, a moon so large it makes Pluto wobble. Even tiny asteroids can have moons. In 2017, scientists found asteroid 3122 Florence had two tiny moons.

Source: https://solarsystem.nasa.gov/solar-system/our-solar-system/in-depth/

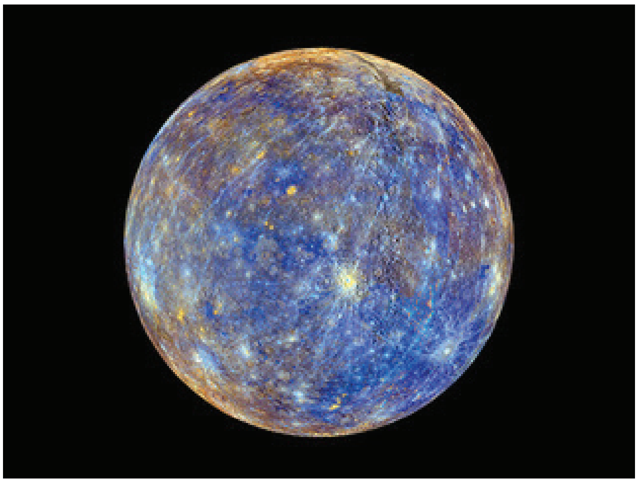
**Planets in our solar system**

There are more planets than stars in our galaxy. The current count orbiting our star: **eight**.
The inner, rocky planets are Mercury, Venus, Earth and Mars. The outer planets are gas giants Jupiter and Saturn and ice giants Uranus and Neptune.

Beyond Neptune, a newer class of smaller worlds called dwarf planets reign, including perennial favorite Pluto.

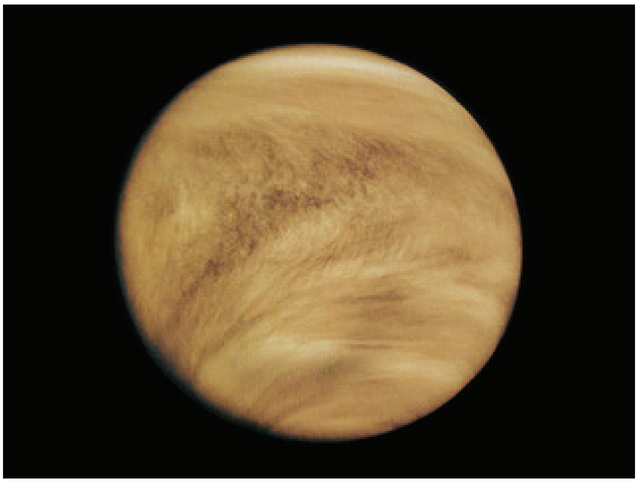
Why is Pluto no longer a planet?

The International Astronomical Union (IAU) downgraded the status of Pluto to that of a dwarf planet because it did not meet the three criteria the IAU uses to define a full-sized planet. Essentially Pluto meets all the criteria except one—it "has not cleared its neighboring region of other objects." Pluto is a world with mountains, glaciers, craters and a thin atmosphere. It is not called a planet anymore, but it's a very well-loved dwarf planet in the Kuiper Belt.



## Mercury

Mercury—the smallest planet in our solar system and closest to the Sun—is only slightly larger than Earth's Moon. Mercury is the fastest planet, zipping around the Sun every 88 Earth days.

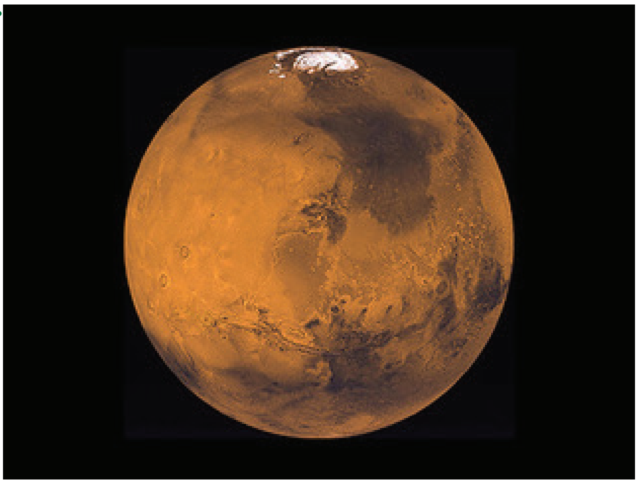


## Venus

Venus spins slowly in the opposite direction from most planets. A thick atmosphere traps heat in a runaway greenhouse effect, making it the hottest planet in our solar system.

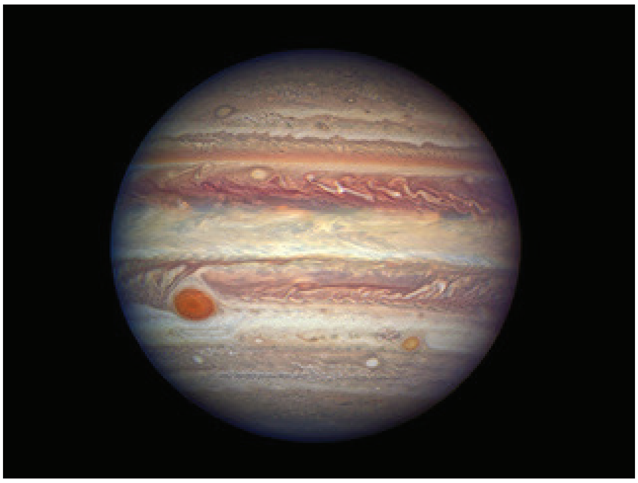
## Earth

Earth—our home planet—is the only place we know of so far that's inhabited by living things. It's also the only planet in our solar system with liquid water on the surface.



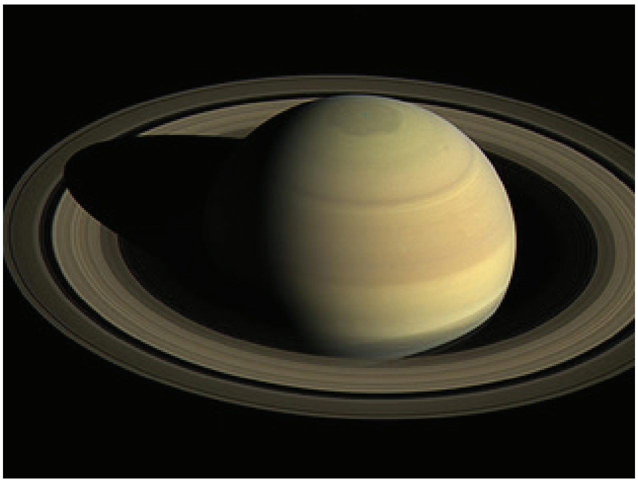
## Mars

Mars is a dusty, cold, desert world with a very thin atmosphere. There is strong evidence Mars was—billions of years ago—wetter and warmer, with a thicker atmosphere.



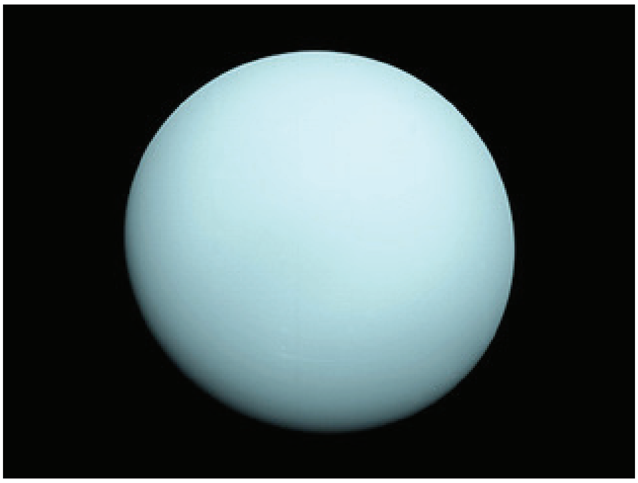
## Jupiter

Jupiter is more than twice as massive than the other planets of our solar system combined. The giant planet's Great Red spot is a centuries-old storm bigger than Earth.



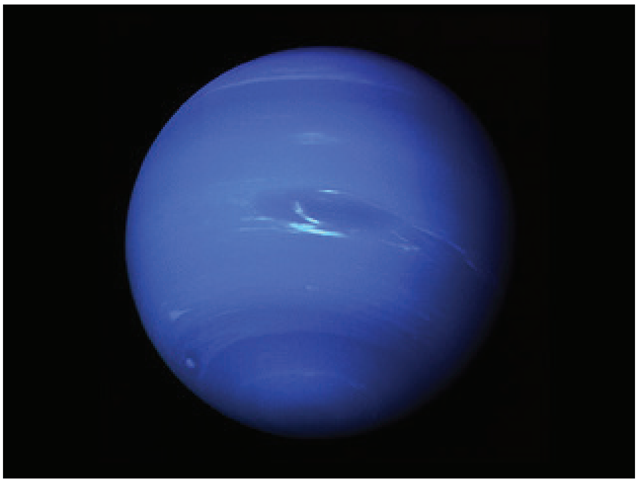
## Saturn

Adorned with a dazzling, complex system of icy rings, Saturn is unique in our solar system. The other giant planets have rings, but none are as spectacular as Saturn's.



## Uranus

Uranus—seventh planet from the Sun—rotates at a nearly 90-degree angle from the plane of its orbit. This unique tilt makes Uranus appear to spin on its side.



## Neptune

Neptune—the eighth and most distant major planet orbiting our Sun—is dark, cold and whipped by supersonic winds. It was the first planet located through mathematical calculations.

## Topic 2 : Space Equipment, Usage and Functions

| | |
|---|---|
| **Content standard** | Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space. |
| **Benchmark** | **10.4.4.23 E**xplore and explain the origin and evolution of stars, star systems, and galaxies. |
| **Key question** | 1. What are the different space equipment?<br>2. What are the functions of the space equipment?<br>3. How do these space equipment help the study and development of aerospace industry |
| **Learning objectives** | By the end of the topic, the students will be able to;<br>• Identify the different space equipment<br>• Explain the functions of the space equipment<br>• Analyse how space equipment help the study and development of aerospace industry |
| **Vocabulary** | Space technology, aerospace, spacecraft, |
| **Knowledge** | • Functions of space equipment/technology<br>• Aerospace Industry |
| **Skills** | Comparing , generating ideas, visualising, modelling, simulating |
| **Attitudes and values** | Open-minded, appreciative, responsible |
| **Teaching and Learning strategies** | Teachers prepare information (including pictures) and ask questions on the space technology while students will use the information provided to answer questions about the topic. |
| **Assessment** | 1. Research on the history of the aerospace industry<br>2. Research and make model of space craft or space equipment and functions |
| **Materials** | Pictures of space equipment/technology |

### Content Background

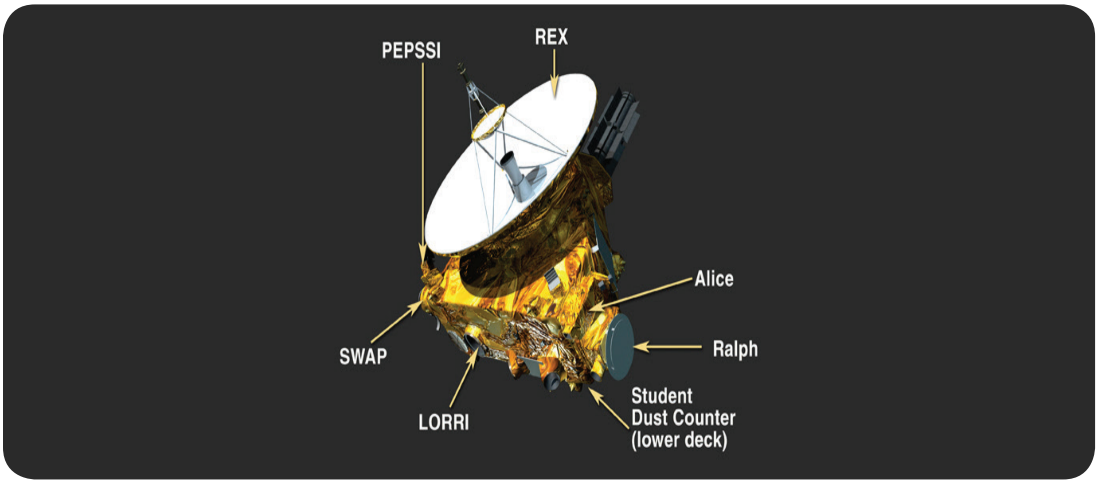
Space technology is technology developed by space science or the aerospace industry for use in spaceflight, satellites, or space exploration. Space technology includes spacecraft, satellites, space stations, and support infrastructure, equipment, and procedures and space warfare. Space is such a novel environment that attempting to work in it requires new tools and techniques. Many common everyday services such as weather forecasting, remote sensing, GPS systems, satellite television, and some long-distance communications systems critically rely on space infrastructure. Of the sciences, astronomy and Earth science benefit from space technology. New technologies originating with or accelerated by space-related endeavors are often subsequently exploited in other economic activities.

What are the instrument used to observe the universe?
The key instrument of nearly all modern observational astronomy is the telescope. This serves the dual purposes of gathering more light so that very faint objects can be observed, and magnifying the image so that small and distant objects can be observed.

The Hubble Space Telescope has three types of instruments that analyze light from the universe: cameras, spectrographs and interferometers.

**Spacecraft and Instruments**

Spacecraft instruments are selected to meet a mission's science goals. On New Horizons, for example, NASA set out a list of things it (and the planetary science community) wanted to know about Pluto: What is its atmosphere made of, and how does it behave? What does the surface of Pluto look like? Are there big geological structures? How do particles ejected from the sun (known as the solar wind) interact with Pluto's atmosphere?




***Credits: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute***

The New Horizons team selected instruments that not only would directly measure NASA's items of interest, but also provide backup to other instruments on the spacecraft should one fail during the mission.

The science payload includes seven instruments:

**Ralph:** Visible and infrared imager/spectrometer; provides color, composition and thermal maps.

**Alice:** Ultraviolet imaging spectrometer; analyzes composition and structure of Pluto's atmosphere and looks for atmospheres around Charon and Kuiper Belt Objects (KBOs).

**REX:** (Radio Science EXperiment) Measures atmospheric composition and temperature; passive radiometer.

**LORRI:** (Long Range Reconnaissance Imager) telescopic camera; obtains encounter data at long distances, maps Pluto's farside and provides high resolution geologic data.

**SWAP:** (Solar Wind Around Pluto) Solar wind and plasma spectrometer; measures atmospheric "escape rate" and observes Pluto's interaction with solar wind.

**PEPSSI:** (Pluto Energetic Particle Spectrometer Science Investigation) Energetic particle spectrometer; measures the composition and density of plasma (ions) escaping from Pluto's atmosphere.

**SDC:** (Student Dust Counter) Built and operated by students; measures the space dust peppering New Horizons during its voyage across the solar system.
*https://www.nasa.gov/mission_pages/newhorizons/spacecraft/index.html*

Other Instruments for space exploration

Examples of Direct-Sensing Science Instruments

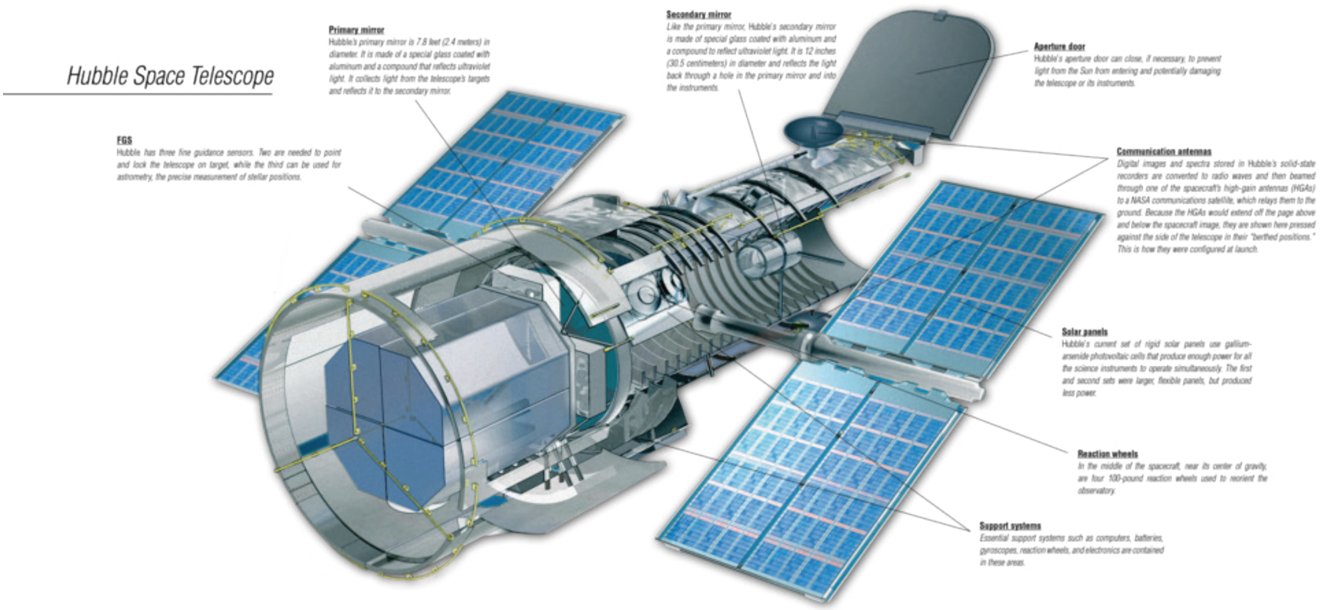
- High-energy Particle Detectors. Voyager's Cosmic Ray Subsystem (CRS). ...
- Low-Energy Charged-Particle Detectors. ...
- Plasma Instruments. ...
- Dust Detectors. ...
- Magnetometers. ...
- Plasma Wave Detectors. ...
- Mass Spectrometers. ...
- Planetary Radio Astronomy Instruments.

The Mobile Service System (MSS)

- The Mobile Service System (MSS), better known by its primary component Canadarm2, is a robotic system and associated equipment on the International Space Station. It play a key role in station assembly and maintenance: moving equipment and supplies around the station, supporting astronauts working in space, and servicing instruments and other payloads attached to the space station. Astronauts receive specialized training to enable them to perform these functions with the various systems.
- The MSS is composed of the actual arm called Space Station Remote Manipulator (SSRM), the Mobile Remote Service Base System (MBS) and the Special Purpose Dexterous Manipulator (SPDM), also known as Dextre or Canada hand.

The Hubble Space Telescope was the first astronomical observatory to be placed into orbit around Earth with the ability to record images in wavelengths of light spanning from ultraviolet to near-infrared. Launched on April 24, 1990, aboard the Space Shuttle Discovery, Hubble is currently located about 340 miles (547 km) above Earth's surface, where it completes 15 orbits per day — approximately one every 95 minutes. The satellite moves at the speed of about five miles (8 km) per second, fast enough to travel across the United States in about 10 minutes.

**The Telescope**




Cutaway diagram of the Hubble Space Telescope, with components labeled.
Credits: NASA's Goddard Space Flight Center

### The Spacecraft

Hubble is 43.5 feet long (13.2 m) and 14 feet wide (4.2 m) at the back, where the scientific instruments are housed. Weighing about 27,000 pounds (12,246 kg), the telescope is approximately the same size and weight as a school bus. The observatory is powered by two solar arrays that convert sunlight into electrical energy that is stored in six large batteries. The batteries allow the observatory to operate during the shadowed portions of Hubble's orbit when Earth blocks the satellite's view of the Sun.

In the middle of the spacecraft, near its center of gravity, are four 100-pound (45 kg) reaction wheels used to reorient the observatory. Based upon Sir Isaac Newton's Third Law of Motion — for every action there is an equal and opposite reaction — turning a reaction wheel in one direction causes Hubble to react by turning the opposite way. The satellite knows where and when it should turn based on a target schedule uploaded from the control center. Hubble's main computer then calculates which wheels should slow and which ones spin faster to most efficiently maneuver the spacecraft to the new target.

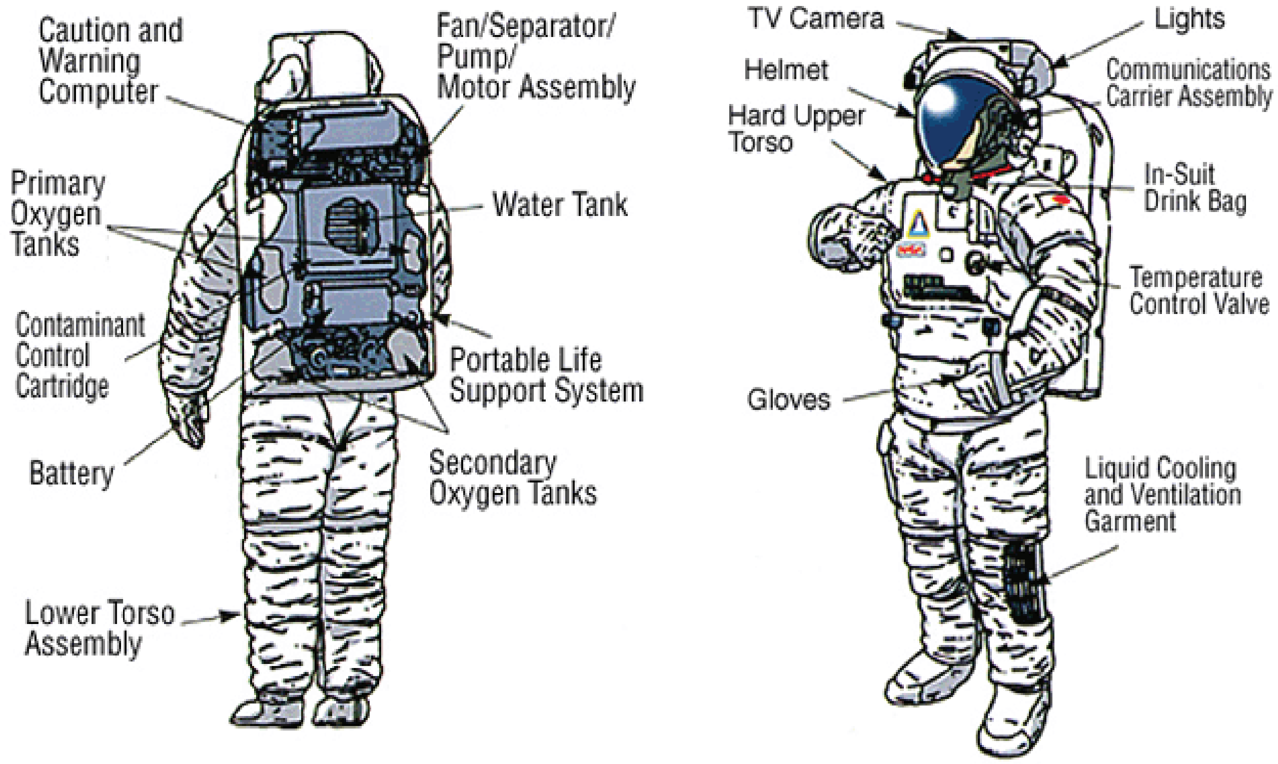
The observatory uses high-precision gyroscopes (gyros) to detect its rate and direction of motion. Hubble's typical operating mode uses three gyros, but it has six from which to choose. The others serve as backups, as gyros eventually wear out and fail. Backup operating modes also exist that enable Hubble to continue collecting science data with only one gyro, if necessary, but with slightly less efficiency.

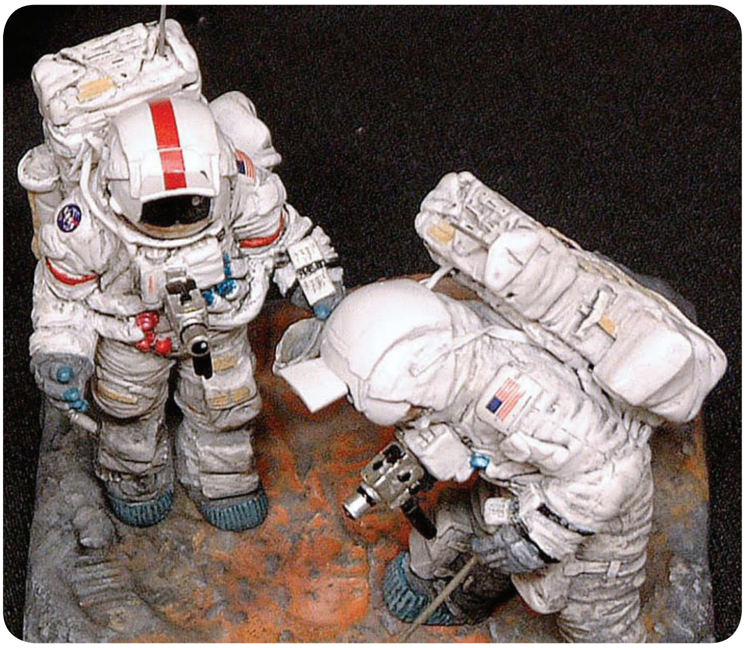
In addition to gyros, Hubble has three Fine Guidance Sensors (FGSs) that act within the spacecraft's overall pointing and control system to keep the telescope virtually motionless while observing. Hubble jitters less than 7 milliarcseconds in a 24-hour period when locked on its target. This is equivalent to shining a laser on a dime 200 miles away for this period.

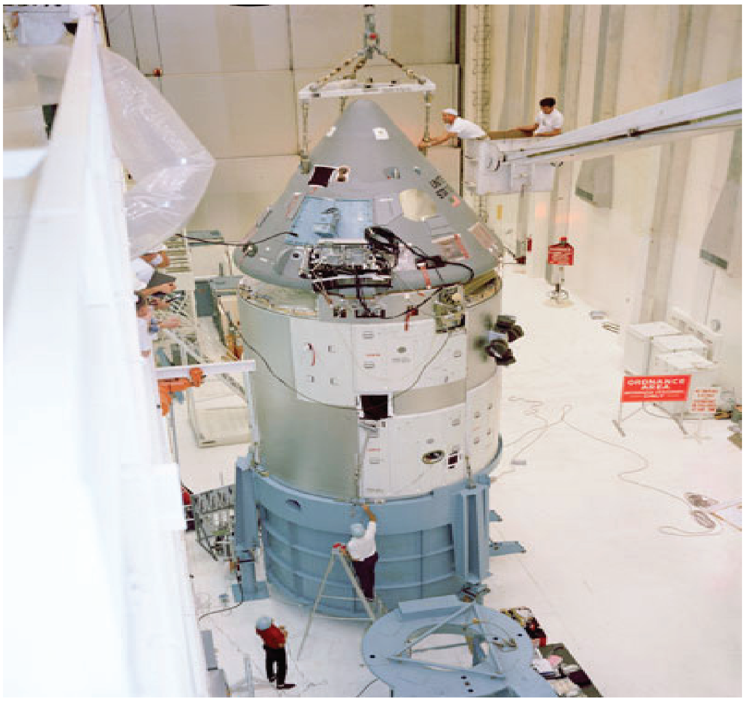
Commands and data are transmitted between the spacecraft and the control center through two high-gain antennas that communicate through NASA's Tracking Data and Relay Satellite System, which is in geosynchronous orbit. The science data is then forwarded from the control center to the Space Telescope Science Institute via a wide-area network for processing, dissemination, and archiving.

NASA has conducted five astronaut-servicing missions to repair and upgrade Hubble. These refurbishments, along with the redundancies originally designed into the observatory's critical subsystems, should keep Hubble running for years to come. Based on formal reliability studies, engineers believe that there is a high probability that Hubble's instruments and primary spacecraft subsystems (gyros, reaction wheels, solar arrays, batteries, etc.) will continue to operate well into the 2020s. NASA's goal is to operate Hubble concurrently with the James Webb Space Telescope, the agency's new and most capable infrared observatory, planned for launch in 2021.

Space Suit


Caution and Warning Computer
Fan/Separator/ Pump/ Motor Assembly
Primary Oxygen Tanks
Water Tank
Contaminant Control Cartridge
Portable Life Support System
Battery
Secondary Oxygen Tanks
Lower Torso Assembly
TV Camera
Lights
Helmet
Communications Carrier Assembly
Hard Upper Torso
In-Suit Drink Bag
Temperature Control Valve
Gloves
Liquid Cooling and Ventilation Garment




ORDNANCE
AREA


USA

# Standards-Based Lesson Planning

## What are Standards-Based Lessons?

In a Standards-Based Lesson, the most important or key distinction is that, a student is expected to meet a defined standard for proficiency. When planning a lesson, the teacher ensures that the content and the methods of teaching the content enable students to learn both the skills and the concepts defined in the standard for that grade level and to demonstrate evidence of their learning.
Planning lessons that are built on standards and creating aligned assessments that measure student progress towards standards is the first step teacher must take to help their students reach success. A lesson plan is a step-by-step guide that provides a structure for an essential learning.
When panning a standards-based lesson, teacher instructions are very crucial for your lessons. How teachers instruct the students is what really points out an innovative teacher to an ordinary teacher. Teacher must engage and prepare motivating instructional activities that will provide the students with opportunities to demonstrate the benchmarks. For instance, teacher should at least identify 3-5 teaching strategies in a lesson; teacher lectures, ask questions, put students into groups for discussion and role play what was discussed.

## Why is Standards-Based Lesson Planning Important?

There are many important benefits of having a clear and organized set of lesson plans. Good planning allows for more effective teaching and learning. The lesson plan is a guide and map for organizing the materials and the teacher for the purpose of helping the students achieve the standards. Lesson plans also provide a record that allows good, reflective teachers to go back, analyze their own teaching (what went well, what didn't), and then improve on it in the future.

Standards-based lesson planning is vital because the content standards and benchmarks must be comparable, rigorous, measurable and of course evidence based and be applicable in real life that we expect students to achieve. Therefore, teachers must plan effective lessons to teach students to meet these standards. As schools implement new standards, there will be much more evidence that teachers will use to support student learning to help them reach the highest levels of cognitive complexity. That is, students will be developing high-level cognitive skills.

## Components of a Standards-Based Lesson Plan

An effective lesson plan has three basic components;

- aims and objectives of the course,
- teaching and learning activities,
- assessments to check student understanding of the topic.

Effective teaching demonstrates deep subject knowledge, including key concepts, current and relevant research, methodologies, tools and techniques, and meaningful applications.

## Planning for under-achievers NORMA

Who are underachieving students?
Under achievers are students who fail or do not perform as expected. Underachievement may be caused by emotions (low self-esteem) and the environment (cultural influences, unsupportive family)

How can we help underachievement?
Underachievement varies between students. Not all students are in the same category of underachievement.
Given below a suggested strategies teachers may adopt to assist underachievers in the classroom.

- Examine the Problem Individually

It is important that underachieving students are addressed individually by focusing on the student's strengths.

- Create a Teacher-Parent Collaboration

Teachers and parents need to work together and pool their information and experience regarding the child. Teachers and parents begin by asking questions such as;

- In what areas has the child shown exceptional ability?
- What are the child's preferred learning styles?
- What insights do parents and teachers have about the child's strengths and problem areas?

- Help student to plan every activity in the classroom
- Help students set realistic expectations
- Encourage and promote the student's interests and passions.
- Help children set short and long-term academic goals
- Talk with them about possible goals.
- Ensure that all students are challenged (but not frustrated) by classroom activities
- Always reinforce students

## A sample guidelines on how to develop a simple STEAM lesson – An Inquiry based

To understand better about STEAM lesson planning, let's study this scenario of a teacher who also wanted to know this.

An Inquiry Based Question
What? We're not going to start with science?  In order to make a good STEAM lesson, we need good bones. An inquiry based question will give us those bones. What do I mean by "inquiry based"?
An inquiry based question causes the student to stop and think. It is impossible to answer with a one syllable answer. It also has:

- Multiple solutions
- Multiple ways of getting to the solution
- Interest

Is the question "What is 9 + 5" inquiry based? No, this question is fact based. The student can answer in one syllable. In this case 14.
A better question would be "How many ways can you make 14?"

The **example problem** we are going to use is "How many rectangles can you make that have an area of 24?"
While the interest isn't super high on this problem, it's a lot higher than a worksheet with the instructions "find the area".
I almost always use math as my starting point because I'm a math teacher. It's what I know. But you could easily start with any of the other subjects.

**For example:**
**S** – " How do plants grow?" or a more specific example, "What is the best fertilizer to grow tomatoes?"
**T** – "Let's make a computer game!"
**E** – "What is the best shape to make a tower out of?"
**M** – "Let's budget and plan a vacation."

Bonus subject **A** (Arst) – "Do different colours elicit different emotions?"
Once you have the basic question hammered out, it becomes easy to add the different subjects in.

**How Does Science Fit in the STEAM Lesson?**
Scientists observe the natural world. Thinking about your starter problem, what can you add to that lesson that would help your students observe the world around them? Or how can you relate your problem to the world around them?
With my example problem, I might think about why someone would care about different size rectangles.

Maybe we are building flower beds and want to know the best shape for a flower bed. As a bonus for me (because I homeschool) we could actually build the flower bed. Now our project ties into the real world, and it's something someone might actually need to do.

And if I actually build the flower bed, we add even more science by observing our plants and noticing what makes them thrive, or not.

Some key words to think about when thinking about science, what can my students:

- observe
- explore
- wonder
- predict
- hypothesize

**How Does Technology Fit in the STEAM Lesson?**
Technology can sometimes be a hard one to fit into a lesson. Especially if you are not tech friendly.

Start with the technology that you use that enhances your life. My idea of using technology for this lesson would be to have them take a picture of their finished plans and share it on Facebook. That's technology, right?

Well, it's better than nothing.
As lesson designers, we also need to keep our students' experience in mind. For my students (who are younger than 10), posting something to Facebook is a new experience and might be a valuable add to the lesson.
It might help to make a list of what we could do with technology.
I would encourage you to add technology to lessons that require doing on the students' part.
While watching a movie is technically technology, they aren't really gaining any technological understanding by watching it.
Here are some examples of some programs that might be helpful for a student to learn to use:

- Publisher
- Excel
- PowerPoint
- Video editing software
- Picture editing software
- Graphing calculator

I find it easiest to add technology in two places: gathering and organizing data and sharing results.

Perhaps with our problem, we will have students make an advertisement on publisher for the size of flower bed they want to create with a goal of mom picking their size.
For more ideas on incorporating technology, see this introduction to exploring with graphing calculators.

**How Does Engineering Fit in the STEAM Lesson?**
Engineers design. They have an emphasis on testing limits: the highest, strongest, longest lasting, etc…
The engineering in STEM also refers to following the Engineering Design Process.
It looks a lot like the Scientific Method that I grew up with. Basically, you define the problem, then try a bunch of stuff until you find the solution.
If you want details (in a handy flow chart no less) visit Science Buddies.

Engineers:
- Design
- Build
- Create
- Test

In my problem, I might add a secondary problem. Which size is going to be the strongest? Or perhaps, the most efficient?

Then my students could build models and test their theories.

**How Does Mathematics Fit in the STEAM Lesson?**
Mathematics is the study of patterns.
Does that definition surprise you? Our current education model has math as a skill set for solving problems. And it certainly has that too. But the reason for that skill set is in finding patterns.
Ask yourself, is there a pattern we can discover with the lesson I am creating?
In my lesson, I would want my students to figure out a quick way to find the area of a rectangle.
So, a question I would have as part of their lesson is, "How did you find the area of this rectangle, now, how can you apply that information to all rectangles?"

**Bonus Subject: Art – How does Arts fit in?**
Artists are also designers.
But unlike their engineering counterpart, their focus is on communicating ideas and beauty.
Like technology, the easiest place to add art is in the end when it's time to communicate findings.

Under the technology section, I decided I would have my students create a poster to convince me of which size garden to create.
Perhaps though, I would do the poster in stages.
Stage 1: Get your ideas on the poster.
Stage 2: Make it beautiful.

**Putting a STEAM Lesson Together:**
Now that you have all of the pieces on your STEAM lesson key ideas, it's time to put them in a sentence or two and see how they fit into a lesson plan.

My focus for this lesson is: Students will test, design, and create a flower bed that has an area of 10 m by 30 cm. They will create a persuasive poster to sell their idea to the class and myself.

## Standards-Based Lesson Planning

The following sample lesson can help teachers to plan effective lessons. Teachers are encouraged to study the layout of the different components of these lessons and follow this design in their preparation and teaching of each lesson. Planning a good lesson helps the teacher in maintaining a standard teaching pattern which should not deviate students learning of the concept from the topic.

### Sample Standards-Based Lesson Plan (Integrating STEAM)

**Topic: The Solar System and beyond**
**Lesson Topic:** Properties of planets, and other components of the solar system
**Grade: 10**
**Length of Lesson:** 80 minutes

Teachers can adjust this lesson for other grades. It is the concepts, content and skill that are important for that grades. The process is the same and is a applicable for all grades.

**National Content Standard:**
**10.4.4** Students will be able to recognise and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space

**Grade Level Benchmark: 10.4.4.21** Investigate and understand scientific concepts related to the origin and evolution of the universe.

**Essential Knowledge, Skills, Values, and Attitudes**

**Knowledge:** Subject and discipline-based knowledge
**Skills:** Evaluating – Reasoning-Calculating, approximating
**Values:** Common Good and interdependence
**Attitudes:** Cooperatively collaborate, betterment of human kind

**STEAM Knowledge and Skill**

**Knowledge:** Calculation process, relative sizes of the 8 planets
**Skill:** Evaluating, reasoning, comparing, measuring, make model

**Performance Indicator:**
Identify correct formula to calculate the relative/approximate sizes of the 8 planets using ratio and scale.

**Materials:** Clay, plasticines, paint, scientific calculators, paint, watercolours, paint brushes, scrap/crepe papers, weighing machines, clear papers, strings, 1 meter sticks, markers, card boards, table of universal relative sizes of the 8 planets from textbook

- **Lesson Objective:** Students will be able to compare and construct the relative/approximate sizes of the 8 planets in our solar system.

**Essential Questions:**

What is the largest planet in the solar system?
What is the smallest planet in the solar system?
How do I correctly calculate the relative/approximate size of the 8 planets? (they are so huge)
What STEAM principles and practices can be used to construct the relative/approximate size of the 8 planets in our solar system?

- Analyse the context and background, and clearly define the problem.
- Conduct research to determine design criteria, financial or other constraints, and availability of materials.
- Generate ideas for potential solutions, using processes such as brainstorming, mathematical calculations, design, and sketching.
- Choose the best solution.
- Build a prototype or model.
- Test and evaluate the solution.
- Repeat steps if necessary to modify the design or correct faults, especially scaling and ratio.
- Reflect and report on the process.

## Lesson Procedure

| Teacher Activities | Student Activities |
|---|---|
| **Introduction** | |
| • Explain what students will learn and how it will be useful.<br>• Connect what they will learn to prior learning or experience. | • Listen to the teacher. |
| **Body** | |
| **Modeling** | |
| • Analyse the context and background of the 8 planets, and clearly define the problem. (how to scale and calculate ratio)<br>• Conduct research to determine design criteria, other constraints, and availability of materials of the 8 planets.<br>• Generate ideas for potential solutions, using processes such as brainstorming, calculating using scales and ratio, and sketching.<br>• Choose the best solution.<br>• Build a prototype or model of the 8 planets.<br>• Test and evaluate the relative sizes of the 8 planets.<br>• Repeat steps as necessary to modify the design or correct faults.<br>• Reflect and report on the process. | • Listen and respond when prompted by the teacher.<br>• Discuss and defend your hypothesis within the group-brainstorming<br>• Discuss and identify correct formulas for ratio and scaling<br>• Distribute tasks of sketching of the prototype within the group<br>• Construct the prototype cooperatively and collaboratively<br>• Test and evaluate the relative sizes of the 8 planets.<br>• Repeat steps as necessary to modify the design or correct faults, especially your measurements.<br>• Reflect and report on the process. |
| **Guided Practice** | Refer to above |
| • Give students the set project/task<br>• Ask students to go about carrying out the task.<br>• Ascertain if students understand what they are supposed to do. | Refer to above |
| **Independent Practice** | |
| • Supervise and facilitate | • Work in their groups on the project/task |
| **Conclusion** | |
| • Ascertain if students understand what they are supposed to do. | • Listen to the teacher.<br>• Present or display models to the class |

### Performance Assessment and Standards

<table>
<tr><td colspan="5">National Content Standard: 10.4.4. Students will be able to recognise and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space</td></tr>
<tr><td>Lesson Topic</td><td>Topic</td><td>Benchmark</td><td colspan="2">Performance Assessment</td></tr>
<tr><td rowspan="4">Properties of planets, and other components of the solar system</td><td>The Solar System and beyond</td><td>10.4.4.21. Investigate and understand scientific concepts related to the origin and evolution of the universe.</td><td colspan="2">Student correctly designs and makes a model of the solar system based on their relative/approximate sizes.</td></tr>
<tr><td colspan="4">PROFICIENCY RUBRIC</td></tr>
<tr><td>Advanced</td><td>Proficient</td><td>Partially Proficient</td><td>Novice</td></tr>
<tr><td>Identify all the 8 planets with the correct relative/ approximate size and justified at least one reason</td><td>Identify all the 8 planets with the correct relative/ approximate size</td><td>Identify more than 50% of all the 8 planets with the correct relative/ approximate size</td><td>Identify less than 50% of all the 8 planets with the correct relative/ approximate size</td></tr>
</table>

### STEAM Activity

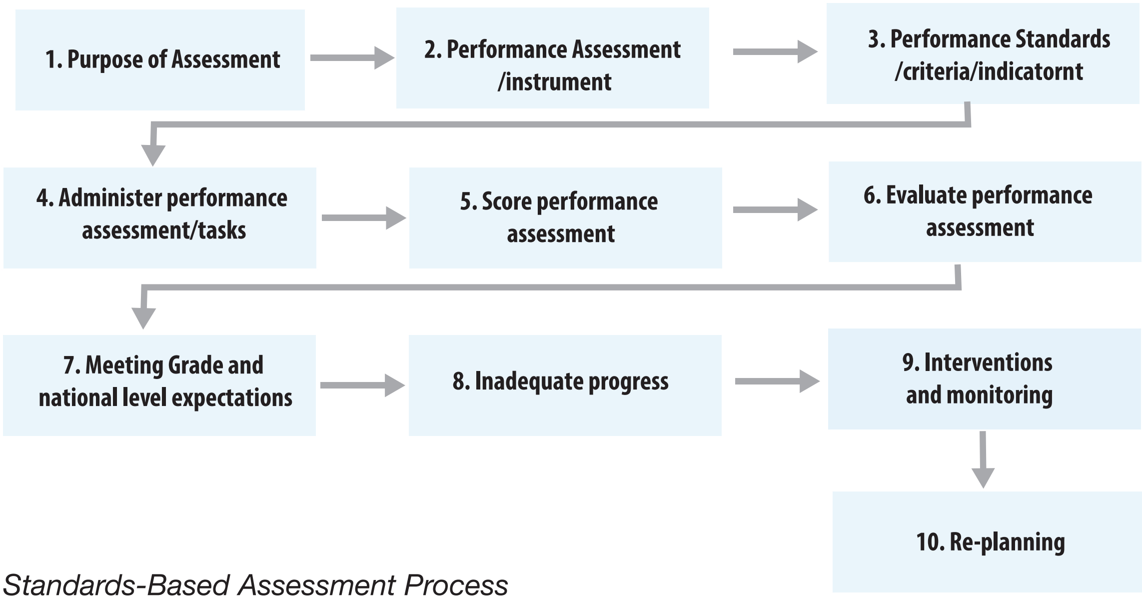
Students create a model of the 8 planets with the correct relative/approximate sizes. Use the information provided in the lesson plan and the guidelines on how STEAM subjects are addressed above for this challenge.

# Assessment, Monitoring and Reporting

## What is Standards-Based Assessment (SBA)?

Assessment and reporting is an integral part of the delivery of any curriculum used in the schools. In Standard Based Curriculum (SBC) assessment encourages the use of benchmarks and commended types of assessment that promote standards for a range of purposes.

*Standards-Based Assessment Cycle*




*Standards-Based Assessment Process*

Teachers are required to use the steps outlined below when planning assessment. These steps will guide you to develop effective assessments to improve student's learning as well as evaluating their progress towards meeting national and grade –level expectations.

## Purpose of Standards-Based Assessment

Standards-Based Assessment (SBA) serves different purposes. These include instruction and learning purposes. The primary purpose of SBA is to improve student learning so that all students can attain the expected level of proficiency or quality of learning.

Enabling purposes of SBA is to:

- Measure students' proficiency on well-defined content standards, benchmarks and learning objectives
- Ascertain students' attainment or progress towards the attainment of specific component of a content standard
- Ascertain what each student knows and can do and what each student needs to learn to reach the expected level of proficiency
- Enable teachers to make informed decisions and plans about how and what they would do to assist weak students to make adequate progress towards meeting the expected level of proficiency
- Enable students to know what they can do and help them to develop and implement strategies to improve their learning and proficiency level
- Communicate to parents, guardians, and relevant stakeholders the performance and progress towards the attainment of content standards or its components
- Compare students' performances and the performances of other students

## Principles of Standards-Based Assessment

The principle of SBA is for assessment to be;

- emphasise on tasks that should encourage deeper learning,
- be an integral component of a course, unit or topic and not something to add on afterward,
- a good assessment requires clarity of purpose, goals, standards and criteria of practices that should use a range of measures allowing students to demonstrate what they know and can do,
- based on an understanding of how students learn of practices that promote deeper understanding of learning processes by developing their capacity for self-assessment,
- for improving performance that involves feedback and reflection,
- on-going rather than episodic,
- given the required attention to outcomes and processes, and

be closely aligned and linked to learning objectives, benchmarks and content standards

## Standards-Based Assessment Types

In standards-Based Assessment, there are three broad assessments types.

**1. Formative Assessment**

Formative assessment includes 'assessment *for* and *as Learning'* and is conducted during the teaching and learning of activities of a topic.

*Purposes of assessment for Learning*

- On-going assessment that allows teachers to monitor students on a day-to-day basis.
- Provide continuous feedback and evidence to the teachers that should enable them to identify gaps and issues with their teaching, and improve their classroom teaching practice.
- Helps students to continuously evaluate, reflect on, and improve their learning.

*Purposes of assessment as Learning*

- Occurs when students reflect on and monitor their progress to inform their future learning goals.
- Helps students to continuously evaluate, reflect, and improve their own learning.
- Helps students to understand the purpose of their learning and clarify learning goals.

**2. Summative Assessment**

Summative assessment focuses on 'assessment *of learning'* and is cconducted after or at the conclusion of teaching and learning of activities or a topic.

*Purposes of assessment of Learning*

- Help teachers to determine what each student has achieved and how much progress he/she has made towards meeting national and grade-level expectations.
- Help teachers to determine what each student has achieved at the end of a learning sequence or a unit.
- Enable teachers to ascertain each student's development against the unit or topic objectives and to set future directions for learning.
- Help students to evaluate, reflect on, and prepare for next stage of learning.

**3. Authentic Assessment**

- Is performed in a real life context that approximates as much as possible, the use of a skill or concept in the real world.
- Is based on the development of a meaningful product, performance or process
- Students develop and demonstrate the application of their knowledge, skills, values and attitudes in real life situations which promote and support the development of deeper levels of understanding.
- Uses either summative or formative assessment methods in real life context.

Authentic assessment refers to assessment that:

- Looks at students actively engaged in completing a task that represents the achievement of a learning objective or standard.
- Takes place in real life situations.
- Asks students to apply their knowledge, skills, values and attitudes in real life situations.
- Students are given the criteria against which they are being assessed.

## Performance Assessment

Performance assessment is a form of testing that requires students to perform a task rather than select an answer from a ready-made list. For example, a student may be asked to explain historical events, generate scientific hypotheses, solve math problems, converse in a foreign language, or conduct research on an assigned topic. Teachers, then judge the quality of the student's work based on an agreed-upon set of criteria. It is an assessment which requires students to demonstrate that they have mastered specific skills and competencies by performing or producing something.

***Types of performance assessment***

*i. Products*

This refers to concrete tangible items that students create through either the visual, written or auditory media such as:

- Creating a health/physical activity poster.
- Video a class game or performance and write a broadcast commentary.
- Write a speech to be given at a school council meeting advocating for increased time for health and physical education in the curriculum.
- Write the skill cues for a series of skill photo's.
- Create a brochure to be handed out to parents during education week.
- Develop an interview for a favourite sportsperson.
- Write a review of a dance performance.
- Essays.
- Projects.

*ii. Process Focused Tasks*

It shows the thinking processes and learning strategies students use as they work such as:

- Survival scenarios.
- Problem solving initiative/adventure/ activities.
- Decision making such as scenario's related to health issues.
- Event tasks such as creating a game, choreographing a dance/gymnastics routine, creating an obstacle course.
- Game play analysis.
- Peer assessment of skills or performances.
- Self-assessment activities.
- Goal setting, deciding a strategy and monitoring progress towards achievement.

*iii. Portfolio*

This refers to a collection of student work and additional information gathered over a period of time that demonstrates learning progress.

*iv. Performances*

It deals with observable affective or psycho-motor behaviours put into action such as:

- Skills check during game play.
- Role plays.
- Officiating a game.
- Debates.
- Performing dance/gymnastics routines.
- Teaching a skill/game/dance to peers.

## Assessment Strategies

It is important for teachers to know that, assessment is administered in different ways. Assessment does not mean a test only. There are many different ways to find out about student's strengths and weaknesses. Relying on only one method of assessing will not reflect student's achievement.

Provided in the table below is a list of suggested strategies you can use to assess student's performances. These strategies are applicable in all the standards-based assessment types.

*ii. Process Focused Tasks*

It shows the thinking processes and learning strategies students use as they work such as:

- Survival scenarios.
- Problem solving initiative/adventure/ activities.
- Decision making such as scenario's related to health issues.
- Event tasks such as creating a game, choreographing a dance/gymnastics routine, creating an obstacle course.
- Game play analysis.
- Peer assessment of skills or performances.
- Self-assessment activities.
- Goal setting, deciding a strategy and monitoring progress towards achievement.

*iii. Portfolio*

This refers to a collection of student work and additional information gathered over a period of time that demonstrates learning progress.

*iv. Performances*

It deals with observable affective or psycho-motor behaviours put into action such as:

- Skills check during game play.
- Role plays.
- Officiating a game.
- Debates.
- Performing dance/gymnastics routines.
- Teaching a skill/game/dance to peers.

## Assessment Strategies

It is important for teachers to know that, assessment is administered in different ways. Assessment does not mean a test only. There are many different ways to find out about student's strengths and weaknesses. Relying on only one method of assessing will not reflect student's achievement.

Provided in the table below is a list of suggested strategies you can use to assess student's performances. These strategies are applicable in all the standards-based assessment types.

## Assessment Strategies

| STRATEGY | DESCRIPTION |
|---|---|
| **ANALOGIES** | Students create an analogy between something they are familiar with and the new information they have learned. When asking students to explain the analogy, it will show the depth of their understanding of a topic. |
| **CLASSROOM PRESENTATIONS** | A classroom presentation is an assessment strategy that requires students to verbalize their knowledge, select and present samples of finished work, and organize their thoughts about a topic in order to present a summary of their learning. It may provide the basis for assessment upon completion of a student's project or essay. |
| **CONFERENCES** | A conference is a formal or informal meeting between the teacher and a student for the purpose of exchanging information or sharing ideas. A conference might be held to explore the student's thinking and suggest next steps; assess the student's level of understanding of a particular concept or procedure; and review, clarify, and extend what the student has already completed |
| **DISCUSSIONS** | Having a class discussion on a unit of study provides teachers with valuable information about what the students know about the subject. Focus the discussions on higher level thinking skills and allow students to reflect their learning before the discussion commences. |
| **ESSAYS** | An essay is a writing sample in which a student constructs a response to a question, topic, or brief statement, and supplies supporting details or arguments. The essay allows the teacher to assess the student's understanding and/or ability to analyse and synthesize information. |
| **EXHIBITIONS/ DEMONSTRATIONS** | An exhibition/demonstration is a performance in a public setting, during which a student explains and applies a process, procedure, etc., in concrete ways to show individual achievement of specific skills and knowledge. |
| **INTERVIEWS** | An interview is a face-to-face conversation in which teacher and student use inquiry to share their knowledge and understanding of a topic or problem, and can be used by the teacher to explore the student's thinking; assess the student's level of understanding of a concept or procedure and gather information, obtain clarification, determine positions, and probe for motivations. |
| **LEARNING LOGS** | A learning log is an ongoing, visible record kept by a student and recording what he or she is doing or thinking while working on a particular task or assignment. It can be used to assess student progress and growth over time. |
| **OBSERVATION** | Observation is a process of systematically viewing and recording students while they work, for the purpose of making programming and instruction decisions. Observation can take place at any time and in any setting. It provides information on students' strengths and weaknesses, learning styles, interests, and attitudes. |
| **PEER ASSESSMENT** | Assessment by peers is a powerful way to gather information about students and their understanding. Students can use set criteria to assess the work of their classmates. |
| **PERFORMANCE TASKS** | During a performance task, students create, produce, perform, or present works on "real world" issues. The performance task may be used to assess a skill or proficiency, and provides useful information on the process as well as the product. |

| | |
|---|---|
| **PORTFOLIOS** | A portfolio is a collection of samples of a student's work, and is focused, selective, reflective, and collaborative. It offers a visual demonstration of a student's achievement, capabilities, strengths, weaknesses, knowledge, and specific skills, over time and in a variety of contexts. |
| **QUESTIONS AND ANSWERS (ORAL)** | In the question–and-answer strategy, the teacher poses a question and the student answers verbally, rather than in writing. This strategy helps the teacher to determine whether students understand what is being, or has been, presented, and helps students to extend their thinking, generate ideas, or solve problems. |
| **QUIZZES, TESTS, EXAMINATIONS** | A quiz, test, or examination requires students to respond to prompts in order to demonstrate their knowledge (orally or in writing) or their skills (e.g., through performance). Quizzes are usually short; examinations are usually longer. Quizzes, tests, or examinations can be adapted for exceptional students and for re-teaching and retesting. |
| **QUESTIONNAIRES** | Questionnaires can be used for a variety of purposes. When used as a formative assessment strategy, they provide teachers with information on student learning that they can use to plan further instruction. |
| **RESPONSE JOURNALS** | A response journal is a student's personal record containing written, reflective responses to material he or she is reading, viewing, listening to, or discussing. The response journal can be used as an assessment tool in all subject areas. |
| **SELECTED RESPONSES** | Strictly speaking a part of quizzes, tests, and examinations, selected responses require students to identify the one correct answer. The strategy can take the form of multiple-choice or true/false formats. Selected response is a commonly used formal procedure for gathering objective evidence about student learning, specifically in memory, recall, and comprehension. |
| **STUDENT SELF-ASSESSMENTS** | Self-assessment is a process by which the student gathers information about, and reflects on, his or her own learning. It is the student's own assessment of personal progress in terms of knowledge, skills, processes, or attitudes. Self-assessment leads students to a greater awareness and understanding of themselves as learners. |

## Samples of Assessment Types

### *Sample 1: Formative Assessment*

**Strand 3: Physical Science**

**Content Standard:** Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.

**Topic:** Electric Current and Circuits

**Benchmark: 10.3.3.2:** Investigate and describe qualitatively the relationship among current, voltage (electric potential difference), and resistance in a simple electric circuit.

**Lesson Title**: Types of Electricity-Circuits-Series Circuit

**Lesson Objective:** By the end of this lesson, students can:
- Construct and explain the relationship between current, voltage and resistance in a series circuit.

**Materials:** Connecting wires, dry cells, bulbs, switch

**What is to be assessed? (KSAVs)**

| Knowledge | Skills | Values and Attitudes |
|---|---|---|
| • Same current flow through each bulb (resistor) in a series circuit.<br>• When the resistors are in series, we add them to work out the total resistance.<br>• The sum of the voltages across the bulb (resistor) is always equal to the dry cell (battery) voltage. | • Constructing and deconstructing.<br>• Discussing and analyzing | • Critical and Appreciative in constructing series circuits.<br>• Creativity and sustainability |

*Scientific Thinking:* Think about the relationship between current, voltage and resistance in a series circuit.

**Purpose of the assessment**
To measure students' proficiency on the achievement of the lesson objective.

**Expected level of proficiency**
Correctly construct a series circuit with 3V power supply, a resistor (light bulb) and measure its current.

**Assessment Strategy**
This lesson is suitable for a double period lab session to complete it. Teacher must group students in advance before the actual lesson.

**Performance Task**

Construct a series circuit to represent given information to solve problems.

**Assessment Tool**

A laboratory practical lesson will be used to measure students' level of proficiency

**Assessment Scoring**

Rubrics must be developed to articulate the real proficiency of the child. This is an analytical rubrics used to assess the child's learning through the assessment tool a lesson exercise.

| Performance standards/ Criteria | A | B | C | D | Score |
|---|---|---|---|---|---|
| | **Advance 10** | **Proficient 7-9** | **Progressing 5-6** | **Not Yet 1-4** | **__/10 Marks** |
| **Construct a series circuit consisting of 6V dry cell and a bulb.** | Correctly constructed of series circuit with cor-rect dry cell voltage and a bulb | Constructed a series circuit consisting of 6V dry cell and a bulb. | Constructed a series circuit with incorrect voltage dry cell and a bulb. | Incorrectly constructed a series circuit consisting of 6V dry cell and a bulb. | |

**Recommended Resources:**

- Outcomes Edition SCIENCE Grade 10
- Fundamental Science for Melanesia Book 3

## *Sample 2: Summative Assessment*

**Strand 3 : Physical Science**

**Content Standard:** Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.

**Topics :** *Chemical Reactions and Equations*

**Benchmark: 10.3.3.5:** Name and write chemical formulas and balance chemical equations.

**Lesson Title:** All the lessons covered in this topic.

**Lesson Objective:** By the end of this lesson, students can:
- Correctly write balanced chemical formulae.

**Materials:** Activity sheet

**What is to be assessed? (KSAVs)**

| Knowledge | Skills | Values and Attitudes |
|---|---|---|
| • Chemical reactions are represented by writing a chemical sentence, which is called a chemical equation. It is a way of representing what happens during a reaction using chemical formulae in place of words. | • Constructing and deconstructing.<br>• Discussing and analyzing | • Critical and Appreciative in constructing series circuits.<br>• Creativity and sustainability |

**Scientific Thinking:** Think about how to write balanced chemical equations.

**Purpose of the Assessment:** To measure students' proficiency on the achievement of the benchmark and learning objectives.

**Expected Level of Proficiency:** Correctly write balanced chemical equations.

**Assessment Strategy:** This lesson can be conducted in one lesson as a unit test, or as an assignment.

**Performance Task:** Write balanced chemical equations.

**Assessment Tool:** An assignment or test will be used to measure students' proficiency.

**Assessment Scoring**

Rubrics must be developed to articulate the real proficiency of the child. This is a sample of an analytical rubric used to assess the child's learning through the assessment tool, an assignment or a test.

| Performance standards/ Criteria | A<br>Advance<br>10 | B<br>Proficient<br>7-9 | C<br>Progressing<br>5-6 | D<br>Not Yet<br>1-4 | Score<br>__/20 Marks |
|---|---|---|---|---|---|
| **(10 marks)**<br><br>Write correct formulae of compounds or elements. | Write all correct formulae of compounds or elements | Write correct formulae of compounds or elements | Write about half of all correct formulae of compounds or elements | Write at least 1 or 2 correct formulae of compounds or elements | |
| **(10 marks)**<br><br>Write correct formulae of compounds or elements. | All chemical formulae written are balanced with states included | Chemical formulae written are balanced with states included | Half the chemical formulae written are balanced with states included | At least 1 or 2 chemical formulae written are balanced with states included | |

Recommended Resources:
- Outcomes Edition SCIENCE Grade 10
- Fundamental Science for Melanesia Book 3

***Sample 4: STEAM Assessment***

(Integrated Strands in relation to the project from integrated subjects)

**Unit:** (Integrated Units from all Subjects in this project)

**Content Standard:** (Integrated Content Standard from all Subjects in project)

**Benchmark:** (Integrated Benchmarks from all Subjects in this project)

**Topic:** (Integrated Topics from all Subjects in this project)

**Lesson topic:** (Integrated Topics from all Subjects in concern)

Instructional Objective (s): Students will be able to;

- Create a STEAM project "building a prototype model of a catapult launching system" to enhance their understand of this concept

| **VASK-MT** | |
|---|---|
| **Values/Attitudes** | Appreciate the beauty of the application of mathematics during the designing process of the project. |
| **Skills** | Calculating size and space Time management and efficiency, Linear measurement and scaling techniques, Calculating mechanical advantage |
| **Knowledge** | Size and space Time management and efficiency, Linear measurement and scaling techniques |
| **Mathematical Thinking** | Think about how to integrate and apply the mathematical knowledge in the project |

**What is to be assessed? - (KSAVs)**

Integrated subjects concepts used designing the projects.

**Purpose of the assessment**

To measure students proficiency on the achievement of the benchmarks and learning objectives for integrated subjects in the project. (STEAM Project)

**Expected level of proficiency**

All students are expected to:

- Build a prototype model of a catapult launching system through integrating concepts learned in other subjects.

**Performance Task**

Student will carry out a project worth 30 marks that should contribute to the School Learning Improvement Program (SLIP). This project will assess students proficiency on the mentioned benchmarks. In order for this assessment type to attain its intended purpose the following must be done carefully;

**Task:** Students will be given a month to complete this project.

1. All grade 9 Science teachers discuss the STEAM project with their HOD
2. The Science HOD brings this project to the attention of the Head Teacher hence it will involve the learning of all grade 10 classes in the school.
3. Once approved by the Head Teacher, the Science HOD now convenes a meeting with all other subject HOD to integrate this project into their learning. HOD for Science will have developed criteria already and will discuss around that.
4. The HOD for other subjects meet with their respective subject teachers to gauge their views and write up criteria's with reference to the theme of the project, "STEM Design and Engineering Challenge" bringing out the essence of their subjects in this project.
5. The Head Teacher then convenes a meeting with all teachers as they are now aware of the project. HOD for respective subjects give feedback from their meetings. Issues concerning this project must be ironed out and all subjects now carry out this assessment, starting with Science.

The grade 10 Science teachers will now do the following;

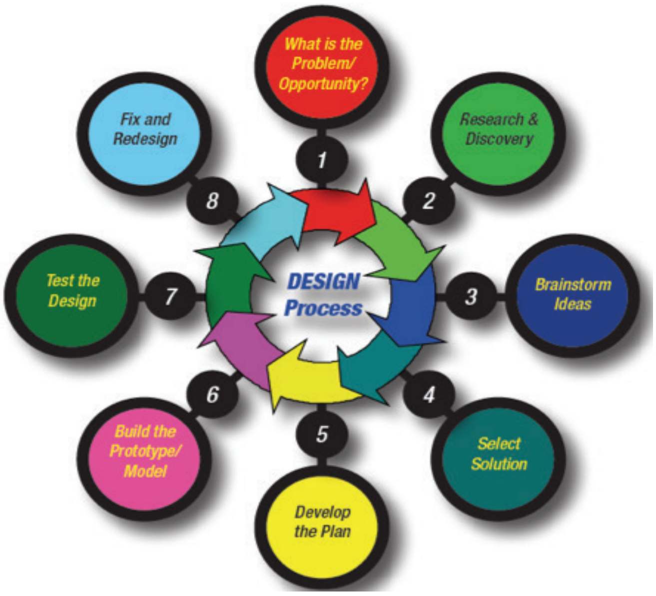
(i) Group the students into groups of 6 to design ( drawing and manual) a tangible technology that will enhance the notion of "building a prototype model of a catapult launching system"

(ii) The teacher then assesses their designs and the best designs now compete with the other best designs from other grade 9 classes.

(iii) All the best designers now create models of their designs with assistance from their class members. At this stage the other subjects now carry forward this assessed projects theme, 'building a prototype model of a catapult launching system" however in the context of their subjects. STEAM is an integrated approach of teaching. All subjects must incorporate the theme put forward by Science. They develop criteria that should address this theme. For instance; Technology and Industrial Arts (TIA) will develop criteria that will engage the students to construct the models. Mathematics teachers will develop criteria to test students' knowledge of the Mathematical thinking process of Engineering Design thinking when they create the models around the theme of "prototype model of a catapult launching system". The English subject teachers will set criteria and guidelines for students on how to write reports so they write to tell others what they have learned and experienced. They must also be given guidelines to writing report. Students get to write report of how they designed this technology. The Science teacher will provide criteria for the students in terms of the physical, chemical, biological and geological properties of the materials used to work out the size and shape of the technology.

Task: Students will be given 6 weeks to complete this project. They are to;

- Design and build a prototype model of a catapult launching system that is easy to use and easy to transport.
- Follow the Design Process to prepare their prototype model in time.
- Write and prepare a short presentation to explain the catapult that was built and the process of building it.




Design Specification:

The catapult should be designed to launch a golf ball at least fifteen feet, to a 18cm x 18cm target.

- The catapult should include a system for determining range, reliability, and accuracy.
- The catapult should be mobile, yet stable. Outriggers or other support systems need to be included to maintain stability when the launcher is used.
- The catapult should be no larger than 30cm long x 30 cm deep x 90cm tall.
- The catapult should feature a locking pin or trigger that activates the catapult to launch.
- Your team should prepare to deliver a presentation about the merits of your catapult model and design.

**Assessment Strategy**

Design Project will be used to measure student's proficiency.

The students will be reinforced in the following STEAM concepts.

*Science*

- Applications of simple machines, including wheels and axles, levers, and pulleys
- Balance and equilibrium
- Energy transformations, such as rotary motion to linear motion
- Mechanical advantage

*Technology and Engineering*

- Prototyping and modelling
- Invention and innovation
- Structural integrity/strength
- Brainstorming and problem solving
- Trial and error engineering concepts

*Arts*

- Sketching and painting

*Mathematics*

- Calculating size and space
- Time management and efficiency
- Linear measurement and scaling techniques
- Calculating mechanical advantage

## Project Rubric

| Category | Advanced | Satisfactory | Partial Credit | Unacceptable |
|---|---|---|---|---|
| | 9 -10 points | 7- 8 points | 1 - 6 points | 0 points |
| **Quality/ Workmanship** | Maximum effort was put forth to complete the project in a professional manner. Project demonstrates a high degree of quality and attention to detail. Workmanship is excellent. | Some effort was made to complete the project to a level that was sufficient for grading, but does not meet a professional level of quality or appearance. Workmanship is of acceptable quality. | Minimal effort was made to complete the project and the quality and workmanship is sub-par, but still meets the minimal standard. | Little or no effort was made to produce a quality project. Project obviously does not meet minimal standards. |
| **Creativity/ Design** | Project reflects many fundamental elements of design and creativity. Project demonstrates an advanced understanding of creative thinking and attention to aesthetics and presentation. | Project reflects some of the elements of design and creativity, but lacks attention to aesthetics and presentation. | Project was completed, but does not reflect the acceptable levels of design and creativity. Effort was minimal and project is mediocre at best. | Project was not completed on time or reflects little or no effort to complete assignment at an acceptable level. |
| **Functionality** | Project meets or exceeds the design requirements of purpose and functionality. All elements of the design have been met and the project does what it was designed to do. | Project meets some of the design requirements of purpose and functionality. Not all elements of the design have been met, but the project does what it was designed to do. | Project is somewhat functional, but reflects minimal effort. It is intermittent and doesn't always do what it was designed to do. | Project does not work and demonstrates a lack of effort or understanding of the basic elements of functionality and purpose. |
| **Design Process** | Project reflects a clear understanding and application of design process including evidence of research, brainstorming, design and problem solving, prototyping and testing. | Project reflects some understanding and application of accepted design loop principles and sequence including evidence of research, brainstorming, design and problem solving, prototyping and testing. | Project reflects minimal under-standing and ap-plication of design process. | Project does not show evidence that design process was used. Project does not meet accepted levels of design criteria. |
| **Criteria/ Constraints** | Project was completed with all constraints and criteria met or exceeded. Reflects attention to detail and quality. | Project was completed with some of the constraints and criteria met. Reflects some attention to detail, but quality is minimal. | Project was com-pleted with a few of the constraints and criteria met. Reflects minimal effort and lacks detail or quality. | Project was not completed and does not reflect the adherence to the constraints or criteria. |

| | | | | |
|---|---|---|---|---|
| **Time Management** | Project completed and turned in on time. Student worked diligently when project time was available. Student was on task most of the time. | Project was completed, but had notable errors. Student utilized project time somewhat efficiently, but spent time socializing. Student was on task 70% - 80% of the time. | Project was not turned in on time and/or complete. The student was on task less than 60% of the time. | Project was not turned in on time and was not completed. Student wasted project time and at times was disruptive to others. |
| **Resource Management** | Always takes responsibility for use and care of all building components and resources. Always returns building components and materials to proper storage compartments. | Consistently takes responsibility for use and care of building components and resources. Somewhat consistent in returning building components to proper storage compartments. | Sometimes takes responsibility for use and care of building components and resources. Inconsistent in returning building components to proper storage compartments. | Does not take responsibility for the proper use and care of building components and resources. Is careless and does not practice proper storage and safety practices. |
| **Teamwork** | Notable teamwork shown with a determination to participate/contribute to team success. Completed required individual tasks that contributed to the success of the team. | Teamwork was noted, but was sometimes off task or working on non-related tasks. Contributed to the success of the team, but could have been more engaged to complete tasks sooner. | Notable time off-task with minimal effort given for team success, or did the project alone without relying on others to do their share of the project. | Was not a team player. Either took over project completely, or did not engage in team direction or plans. |
| **Writing/ Reflection** | Writing/reflection is very well organized and explained. Student includes all details in design process. Document has almost no grammatical errors. | Writing/reflection is somewhat organized and explained. Student includes most details in design process. Document has very few grammatical errors. | Writing/reflection is not organized and explained. Student includes only a few details in design process. Document has many grammatical errors. | Writing/reflection is incomplete or not turned in. Student includes no details in design process. Document has many grammatical errors. |
| **Presentation** | Presentation was well organized and presented in a logical sequence. Presentation reflects a full knowledge of the topic with clear answers and explanations to questions asked. | Presentation was fairly organized and most information presented in a logical sequence. Answers to questions were vague or lacked clarity or accuracy. | Presentation was unorganized and lacked a logical sequence. Presentation reflected little attention to detail. Answers to questions were inaccurate and confusing. | Presentation was not acceptable and reflects a lack of organization or knowledge of the topic. Presentation shows little effort to meet expectations. |

# Glossary

| Words | Definition |
|---|---|
| **Abiotic factor** | The nonliving part of an ecosystem |
| **Allele** | One of different forms of a gene for a trait |
| **Ampere (A)** | The units used to measure the amount of electric current flowing in a conductor |
| **Amplitude** | The maximum distance a wave varies from its rest position |
| **Angiosperm** | A vascular plant that produces seeds from flowers |
| **Assessment** | Activities given to students to measure the progress of their learning |
| **Assessment Strategies** | Different styles and ways of assessing students work |
| **Assessment Tasks** | Test of knowledge and skills gain throughout the particular unit or topic |
| **Benchmark** | Assessment of content standards at the end of each level of schooling |
| **Biochemistry** | The study of chemistry of living things such as plants, animals or people |
| **Biomass** | Once- living matter that can be used as an energy source |
| **Biotechnology** | The use of cells and bacteria in chemical processes, especially in food and chemical industries |
| **Buoyant force** | An upward force applied by a fluid on an object in the fluid |
| **Chromosomes** | Thread-like structures found in the nucleus of cells. They contain the instructions to run the cell. The number of chromosomes in the nucleus is constant for each species, eg, humans have 46. |
| **Concentration** | The amount of a particular solute in a given amount of solution |
| **Conferencing** | A conversation between the teacher and student or in small groups |
| **Constants** | The factors in an experiment that remain the same |
| **Content Standards** | Statements that describe what students should know and do in each subject area |
| **Control test** | A test or experiment where controls and variables are used |
| **Convection current** | A loop of moving gas or liquid caused by rising warm gas or liquid and sinking cool gas or liquid |
| **Cytoplasm** | Materials that surround the internal parts of the cell |
| **Decibel (dB)** | The units used to measure the loudness of sound |
| **Diagnostic Assessment** | An assessment given to identify child's strengths and learning needs for improvement. |
| **Dichotomous key** | A tool used to identify organisms based on contrasting pairs of characteristics |
| **Diffusion** | Process that spreads substances through a gas or liquid from higher to lower concentration |
| **Displacement** | The difference between the initial, or starting position and the final position of an object that has moved |

| | |
|---|---|
| **DNA** | Deoxyribonucleic acid- the genetic material of all living things |
| **Doppler effect** | The change of pitch when a sound source is moving in relation to an observer |
| **Efficiency** | The ratio of output work to input work |
| **Electromagnetic spectrum** | The band of radiation that includes radio waves, microwaves, infrared radiation, visible light, x-rays, ultraviolet light, and gamma rays |
| **Electron** | A negatively charged particle in an atom |
| **Endothermic reaction** | A reaction in which energy is absorbed |
| **Enzyme** | A chemical found in living things that helps control which chemical reactions are to take place |
| **Enzym** | A catalyst that speeds up chemical reactions in living things |
| **Epicenter** | A point on the Earth's surface directly above the location of initial plate boundary movement during an earthquake |
| **Fission** | A nuclear reaction in which atomic nuclei split and release energy |
| **Frequency** | The number of wavelengths that pass by a point each second |
| **Fusion** | The forcing of two small atomic nuclei to join together thus releasing energy |
| **Gene** | A part of a cell that is passed on from parent to child and that controls particular characteristics |
| **Genetic code** | The sequence of three (3) bases (called a triplet or codon) along the DNA or RNA that specifies the next amino acids in the protein |
| **Global Positioning System (GPS)** | A worldwide navigation system that uses satellite signals to determine receiver's location |
| **Gymnosperm** | A vascular plant that produces seeds, but not flowers or fruits |
| **Hazards** | A situation that poses a level of threat to life, health, property or environment |
| **Heterogeneous** | Mixed unevenly |
| **Homogeneous** | Mixed evenly |
| **Homologous structures** | Structures that are similar in different species |
| **Hormone** | The chemical message that travels through the blood and carries special i nformation for certain cells |
| **Hydrocarbon** | A compound that contains only carbon and hydrogen atoms |
| **Hydroelectric energy** | Electric energy generated from moving water |
| **Hypothesis** | A theory or suggested explanation for something that has not yet been proven. |
| **Immune system** | An organ system that fights disease and foreign agents |
| **Inertia** | The tendency of an object to resist a change in its motion |
| **Ion** | An atom that has a different number of electrons than protons |
| **Isotopes** | Atoms with the same number of protons but different number of neutrons |
| **Longitudinal wave** | A wave in which particles move back and forth in the same direction as the wave travels |

| | |
|---|---|
| **Meiosis** | Cell division that reduces the number of chromosomes by half.<br>The special type of cell division which produces the sex cells (sperm and ova). Each sex cell contains half the number of chromosomes normally found in a body cell. |
| **Menstruate** | To have a monthly flow of blood from the uterus |
| **Metalloid** | An element that has physical and chemical properties of both metals and nonmetals |
| **Mitosis** | Cell division that reduces the number of chromosomes by half.<br>The special type of cell division which produces the sex cells (sperm and ova). Each sex cell contains half the number of chromosomes normally found in a body cell. |
| **Molecules** | The smallest unit of a substance, consisting of one or more atoms. |
| **Momentum** | When something continues to move, speed or gain speed. |
| **Mutation** | Any change in a genome or a chromosome |
| **Mutation** | A permanent change in the genes of an organism, or an organism with such a change |
| **Natural phenomena** | Things that happen naturally such as movement of stars, tides, and |
| **Natural selection** | The process by which the organisms that are best adapted to their environment survive and reproduce |
| **Natural selection** | The way the plants and animals die when they are weak or not suitable for the pace where they live, while the stronger ones continue to exist. |
| **Nitrogen fixation** | The process of Nitrogen gas changing into usable nitrogen compounds |
| **Nonvascular** | Lacking a water-transport system |
| **Nuclear energy** | Is the energy stored in the nucleus of an atom. It is the energy that holds the nucleus together. The nucleus of Uranium atom is an example of nuclear energy. |
| **Nucleus** | A part of a cell that directs all activities and carries information for cell reproduction |
| **Observations** | A careful watch over and experiment using Science as Inquiry skills |
| **Opaque** | Not letting light pass through |
| **Optical telescope** | An instrument that gathers light to form an enlarged image of a distant object |
| **Organ** | Two or more type of tissue that work together to perform a function |
| **Organelle** | A structure that has a specific task within the cell |
| **Osmosis** | A type of diffusion that allows water to pass but not the solutes in the water |
| **Parasitism** | The relationship in which one organism lives in or on another organism and harms it in some way. |
| **Performance Standards** | What students must do to demonstrate proficiency |
| **Periodic table** | The table that arranges the elements according to atomic number |
| **pH scale** | System of measuring the strength of different acids and bases |
| **Phagocyte** | A cell that consumes harmful invading organisms in your body |
| **Photon** | A particle of electromagnetic radiation |
| **Plate boundary** | The edge of a tectonic plate |

| | |
|---|---|
| **Polymer** | A substance made of giant molecules formed by the joining of many simple molecules (monomers). For example, the addition polymer polyethylene, or the condensation polymer nylon |
| **Portfolio** | Collections of student work that exhibit the students' efforts, progress and achievements in one or more areas |
| **Practical Tasks** | Activities involving students to display or do both indoor and outdoor |
| **Precipitation** | Any form of water that falls to earth's surface from clouds |
| **Predation** | Interaction in which one organism catches and feeds on an organism of another species |
| **Pressure** | The amount of force exerted per unit area |
| **Protist** | A single-celled or multicellular organism that may share characteristics with plants, fungi and animals |
| **Proton** | A positively charged particle in the nucleus of an atom |
| **Radiation** | When a substance emits electromagnetic waves that carry energy |
| **Rarefaction** | The region of a longitudinal wave where the particles of the medium are farthest apart |
| **Recording** | An act of collecting and entering of raw scores from students through assessable tasks |
| **Reflection** | Light bouncing off a surface |
| **Refraction** | The bending of light rays when they bounce from one material to another |
| **Relationships** | The connection between two or more organisms and their involvement with one another including their abiotic environment |
| | The process of making identical copies of DNA |
| **Replication** | to present parents and guardians correct information about students' academic performance |
| **Reporting** | Complete orbit around an object |
| **Revolution** | A cell structure where proteins are manufactured |
| **Ribosome** | A complete turn about an axis |
| **Rotation** | Skills scientists apply to investigate the nature of sciences in the world. |
| **Science process skills** | The pulling apart of plate boundaries under the ocean floor |
| **Sea-floor spreading** | Development of new communities after an ecosystem has been disturbed |
| **Secondary succession** | When something continues to move, increase or develop to gain momentum |
| **seismic** | A wave that carries the energy released when rock move at plate boundaries |
| **Seismic wave** | A judgment sometimes for official purposes which you make about your abilities, principles or decisions |
| **Self – Assessment** | A system that uses the reflection of sound waves to find underwater objects |
| **Sonar** | Sound is a form of energy, just like electricity and light. Sound is made when air molecules vibrate and move in a pattern called waves, or sound waves. |
| **Sound** | A body of information or statistics gathered over a period of time from students' performance |

| | |
|---|---|
| **Students Records** | A body of information or statistics gathered over a period of time from students' performance |
| **Sustainability** | Able to continuously maintain over a period of time |
| **Symbiosis** | Relationship in which two species live close to each other |
| **Tectonic plate** | An irregular section of the lithosphere that floats on earth's mantle |
| **Tests** | Way of discovering by questions or practical activities to measure someone's knowledge, ability or experience |
| **Thermal equilibrium** | When objects in contact are the same temperature |
| **Thermal expansion** | An increase in size of a sample of matter when it is heated |
| **Transverse wave** | A wave in which particles move up and down or side-to-side at right angles to the direction the wave travels |
| **Transverse wave** | A wave in which the disturbance is perpendicular to the direction the wave travels |
| **Trophic level** | Each step in the movement of energy through a food web |
| **Use variable** | To keep all conditions in an experiment the same except for the variable, or the condition that is being tested in the experiment |
| **Vaporization** | The change in state from liquid to gas |
| **Variable** | Any factor that can have more than one value |
| **Wavelength** | The distance between a point on one wave and the same point on the next wave |
| **X-ray** | A high energy electromagnetic wave that has a slightly shorter wavelength and higher frequency than an ultraviolet wave |

# References


- Assessment in Grade 11 Chemistry, Grade 11 Chemistry, Copyright © 2003 by Manitoba Education and Youth, 12 – Section 3
- Curriculum Framework, Western Australia, 2008
- National Curriculum Standards and benchmarks, Department of Education, Federated States of Micronesia, 2008.
- DOE, 2003, National Curriculum Statement, Department of Education, PNG
- DOE, 2019, National Curriculum Standards Framework, Department of Education, PNG
- Lodish, H,Berk, A., Kaiser, C. A., Krieger, M., Scott, M. P., Bretscher, A., . . . Matsudaira, P. (2008). Molecular Cell Biology 6th. ed. New York: W.H. Freeman and Company.
- Nelson, D. L., & Cox, M. M. (2008). Principles of Biochemistry. New York: W.H. Freeman and Company.

- https://medlineplus.gov/genetics/understanding/basics/gene/
- https://www.britannica.com/story/what-is-the-difference-between-primary-and-secondary-ecological-succession
- **https://byjus.com/biology/ecosystem/**
- **https://science.sciencemag.org/content/356/6335/258**
- https://intl.siyavula.com/read/science/grade-10-lifesciences/biosphere-to-ecosystems/08-biosphere-to-ecosystems-07

# Appendices

## Appendix 1: Bloom's Taxonomy

| LEVEL OF UNDERSTANDING | KEY VERBS |
|---|---|
| CREATING<br>Can the student create a new product or point of view? | Construct, design, and develop, generate, hypothesize, invent, plan, produce, compose, create, make, perform, plan, produce, assemble, formulate, |
| EVALUATING<br>Can the student justify a stand or decision? | Appraise, argue, assess, choose, conclude, critique, decide, defend, evaluate, judge, justify, predict, prioritize, provoke, rank, rate, select, support, monitor, |
| ANALYZING<br>Can the student distinguish between the different parts? | Analyzing, characterize, classify, compare, contrast, debate, criticise, deconstruct, deduce, differentiate, discriminate, distinguish, examine, organize, outline, relate, research, separate, experiment, question, test, |
| APPLYING<br>Can the student use the information in a new way | Apply, change, choose, compute, dramatize, implement, interview, prepare, produce, role play, select, show, transfer, use, demonstrate, illustrate, interpret, operate, sketch, solve, write, |
| UNDERSTANDING<br>Can the student comprehend ideas or concepts? | Classify, compare, exemplify, conclude, demonstrate, discuss, explain, identify, illustrate, interpret, paraphrase, predict, report, translate, describe, classify, |
| REMEMBERING<br>Can the student recall or remember the information? | Define, describe, draw, find, identify, label, list, match, name, quote, recall, recite, tell, write, duplicate, memorise, recall, repeat, reproduce, state, |

## Appendix 2: 21st Century Skills

| | |
|---|---|
| **WAYS OF THINKING** | Creativity and innovation<br>Think creatively<br>Work creatively with others<br>Implement innovations<br>Critical thinking, problem solving and decision making<br>Reason effectively and evaluate evidence<br>Solve problems<br>Articulate findings<br>Learning to learn and meta-cognition<br>Self-motivation<br>Positive appreciation of learning<br>Adaptability and flexibility |
| **WAYS OF WORKING** | Communication<br>Competency in written and oral language<br>Open minded and preparedness to listen<br>Sensitivity to cultural differences<br>Collaboration and teamwork<br>Interact effectively with others<br>Work effectively in diverse teams<br>Prioritise, plan and manage projects |
| **TOOLS FOR WORKING** | Information literacy<br>Access and evaluate information<br>Use and manage information<br>Apply technology effectively<br>ICT literacy<br>Open to new ideas, information, tools and ways of thinking<br>Use ICT accurately, creatively, ethically and legally<br>Be aware of cultural and social differences<br>Apply technology appropriately and effectively |
| **LIVING IN THE WORLD** | Citizenship – global and local<br>Awareness and understanding of rights and responsibilities as a global citizen<br>Preparedness to participate in community activities<br>Respect the values and privacy of others<br>Personal and social responsibility<br>Communicate constructively in different social situations<br>Understand different viewpoints and perspectives<br>Life and career<br>Adapt to change<br>Manage goals and time<br>Be a self-directed learner<br>Interact effectively with others |

## Appendix 3: Standards-Based Lesson Plan Template

### Standards-Based Lesson Plan (Integrating STEAM)

---

**Topic:**

**Lesson Topic:**

**Grade:**

**Length of Lesson:**

---

**National Content Standard**

**Grade Level Benchmark**

### Essential Knowledge, Skills, Values, and Attitudes

**Knowledge:**

**Skills:**

**Values:**

**Attitudes:**

---

**Materials:**

---

- **Lesson Objective:**

**Essential Questions:**

## Lesson Procedure

| Teacher Activities | Student Activities |
|---|---|
| **Introduction** | |
| | |
| **Body** | |
| | |
| **Guided Practice** | |
| | |
| **Independent Practice** | |
| | |
| **Conclusion** | |
| | |

# Appendix 4: Standards-Based Lesson Plan Template-Integrating STEAM

## Standards-Based Lesson Plan (Integrating STEAM)

**Topic:**
**Lesson Topic:**
**Grade:**
**Length of Lesson:**

**National Content Standard**

**Grade Level Benchmark**

## Essential Knowledge, Skills, Values, and Attitudes

**Knowledge:**

**Skills:**

**Values:**

**Attitudes:**

## STEAM Knowledge and Skill

**Knowledge:**

**Skill:**

**Performance Indicator:**

**STEAM Performance Indicator:**

**Materials:**

- **Lesson Objective:**

**Essential Questions:**

## Performance Assessment and Standards

| National Content Standard: | | | | |
|---|---|---|---|---|
| **Lesson Topic** | **Topic** | **Benchmark** | **Performance Assessment** | |
| | | | | |
| | **PROFICIENCY RUBRIC** | | | |
| | **Advanced** | **Proficient** | **Partially Proficient** | **Novice** |
| | | | | |

‘FREE ISSUE - NOT FOR SALE’