

Chemistry

Senior High

Grade 11

Teacher Guide

Standards-Based



Papua New Guinea

Department of Education

'FREE ISSUE

NOT FOR SALE'

Chemistry

Senior High

Grade 11

Teacher Guide

Standards-Based



Papua New Guinea
Department of Education

Issued free to schools by the Department of Education

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First Edition

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Acronyms

AAL	Assessment As Learning
AFL	Assessment For Learning
AOL	Assessment Of Learning
BoS	School Board of Studies
CDD	Curriculum Development Division
CP	Curriculum Panel
CRS	Classroom Response System
DA	Diagnostic Assessment
HOD	Head of Department
IHD	Integral Human Development
MTDG	Medium Term Development Goals
NGO	Non-Government Organisation
PBA	Performance Based Assessment
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
SRS	Student Response System
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics

Secretary's Message

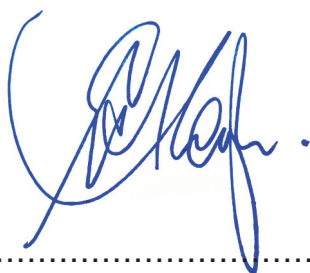
The aims and goals of the SBC identify the important knowledge, skills, values, and attitudes that all students are expected to acquire and master in order to effectively function in society and actively contribute to its development, students' welfare and enable them to acquire and apply 21st Century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

Chemistry is a significant curriculum framework for teaching children and enabling them to progressively develop proficiency on fundamental ideas of, Science as Inquiry, Inorganic Chemistry, Physical Chemistry, Analytical Chemistry, Organic Chemistry and Industrial Chemistry. This curriculum addresses Chemistry skills and processes of sensitive, moral, ethical and environmental issues in the physical world and global awareness.

Thus, students will be able to make informed decisions, problem – solving and management knowledge, skills, values and attitudes in Chemistry. 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.

Chemistry teachers are expected to effectively plan, teach, and assess these knowledge, skills, values, and attitudes. The teacher guide describes what teachers are expected to know and do to enable all their students to effectively learn and demonstrate the expected levels of proficiency in all the grade level Chemistry knowledge, skills, values and attitudes, and attain the national content standards.

I commend and approve this Grade 11 Chemistry Teacher Guide to be used by teachers in all Senior High Schools throughout Papua New Guinea.



.....
UKE W. KOMBRA, PhD
Secretary for Education

Introduction

Chemistry aims to develop and instil in students the ability in questioning, researching and critical scientific thinking. It does this by giving students particular ways of looking at the world and by emphasising the importance of evidence in forming conclusions. Chemistry education develops students' confidence to initiate and manage change to meet personal, vocational and societal needs. Chemistry 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.

The study of Chemistry enhances scientific knowledge, processes and values have the potential to help students build a more productive and physically-sustainable environment and responsible decision making in their local, national and global industries. The course is organised into 5 units. These are Inorganic Chemistry, Physical Chemistry, Analytical Chemistry, Organic Chemistry and Industrial Chemistry. Science as Inquiry is a special unit that is embedded into all units and topics. It has eight lessons at the introduction, but the skills will be looked at throughout the whole course of study in the grade 11 Chemistry

Chemistry 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 should 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.

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 Chemistry curriculum. Equal opportunities should be provided for all students to learn, apply and master STEAM principles and skills.

Time allocation for Chemistry is **240** minutes per week. Teachers are urged to fully utilise the allocated time.

Structure of the Teacher Guide

There are four main components 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, which are morals and values education, cognitive and high level thinking, and 21st Century thinking skills, STEAM, and core curriculum. There 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. Teachers are encouraged 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 of 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 11 Chemistry 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;

- 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 Chemistry syllabi and teacher guide to plan, teach and assess different Chemistry units and topics, and the KSVAs described in the grade-level benchmarks,
- understand the Chemistry national content standards, grade-level benchmarks, and evidence outcomes,
- effectively make sense of the content (KSVAs) described in the Chemistry 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 Chemistry skills, processes, concepts, ideas, principles, practices, values and attitudes,
- confidently interpret, translate and use Chemistry 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 Chemistry 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 and 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 Chemistry 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 and
- 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.

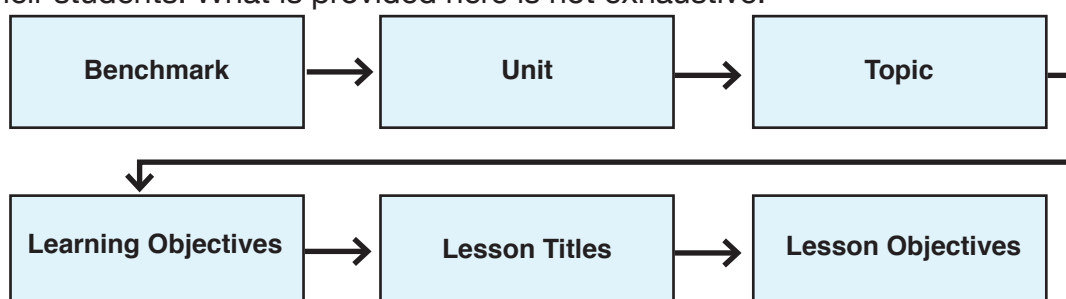
How to use the Teacher Guide

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 11 and 12 Chemistry Curriculum. Based on this understanding, teachers should be able to effectively use the teacher guide to do the following:

Determine Lesson Objectives and Lesson Titles

Units, topics and learning objectives have been identified and described in the Teacher Guide and Syllabus. Learning objectives are derived from topics that are extracted from the grade-level benchmarks. Lesson titles 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 lesson objectives and lesson titles. Teachers should use the examples provided in this teacher guide to formulate additional lesson objectives and lesson titles to meet the educational or learning needs of their students. What is provided here is not exhaustive.



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.

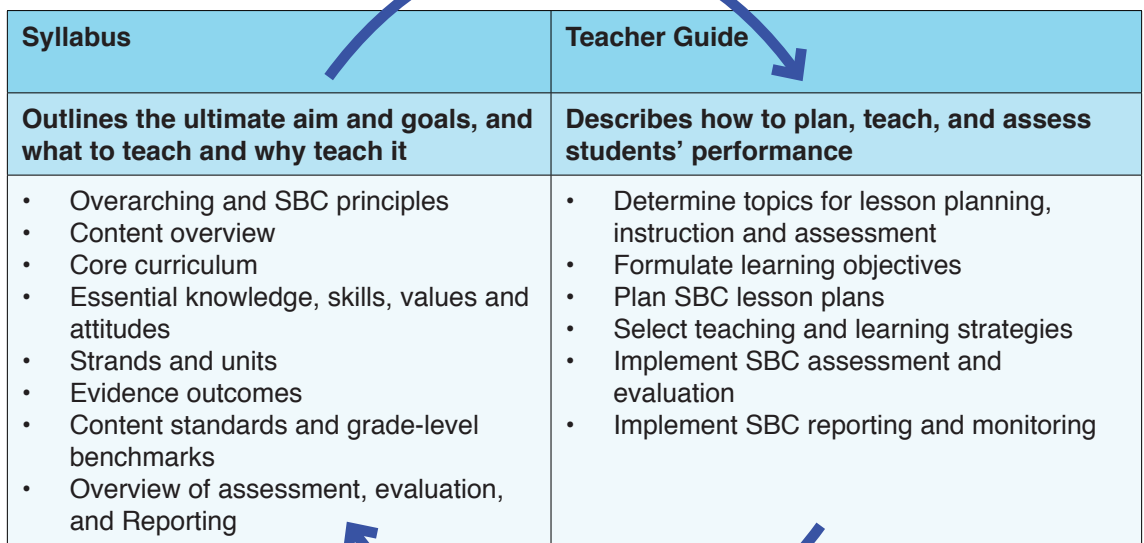
SBC does not mean that the content, lesson objectives, teaching and learning strategies, and assessment are standardised. This is a misconception and any attempt to standardise the components of curriculum without due consideration of the teaching and learning contexts, student's backgrounds and experiences, and different abilities and learning styles of students 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.

This subject 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 Social Science knowledge, skills, values and attitudes.



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
<ul style="list-style-type: none"> • Overarching and SBC principles • Content overview • Core curriculum • Essential knowledge, skills, values and attitudes • Strands and units • Evidence outcomes • Content standards and grade-level benchmarks • Overview of assessment, evaluation, and Reporting 	<ul style="list-style-type: none"> • Determine topics for lesson planning, instruction and assessment • Formulate learning objectives • Plan SBC lesson plans • Select teaching and learning strategies • Implement SBC assessment and evaluation • Implement SBC reporting and monitoring

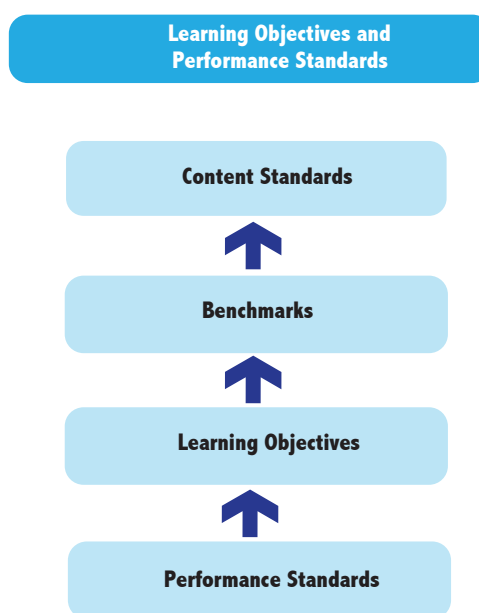
The syllabus outlines the ultimate aim and goals of SBE and SBC, what is to be taught and why it should be learned by students, the underlying principles and articulates the learning and proficiency standards that all students are expected to attain. On the other hand, the teacher guide expands on what 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 Grade 12 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. 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 SBC 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 and
- 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.

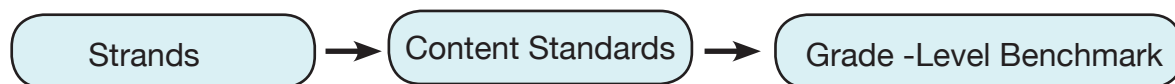
Benchmarks

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 students in other countries.

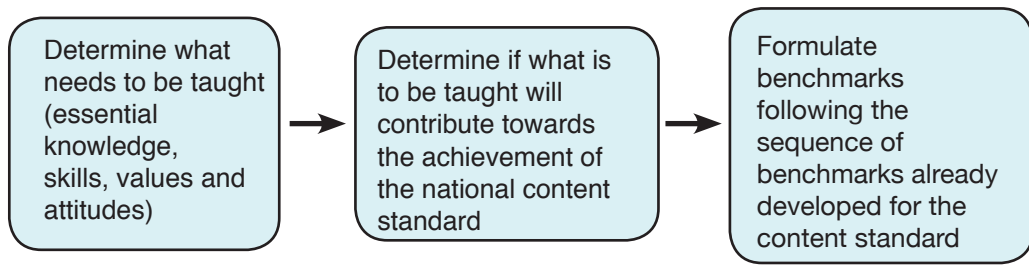
Approach for Setting National Content Standards and Grade-Level Benchmarks



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



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 layers of the earth.

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, and
- 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,
- reading, writing and communication skills,
- STEAM principles and skills,
- essential values and attitudes (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 holistic approach to values and attitudes in teaching, promoting and modeling is critical to students and the whole school community to internalise 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 extra-curricular programs and activities.

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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.

Chemistry 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.
- (v) Build prototypes or models of solutions to problems.
- (vi) Replicate a problem solution by building models and explaining how the problem was or could be solved.
- (vii) Test and reflect on the best solution chosen to solve a problem.
- (viii) Collaborate with others on a problem and provide a report on the process of problem solving used to solve the problem.
- (ix) 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. 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.

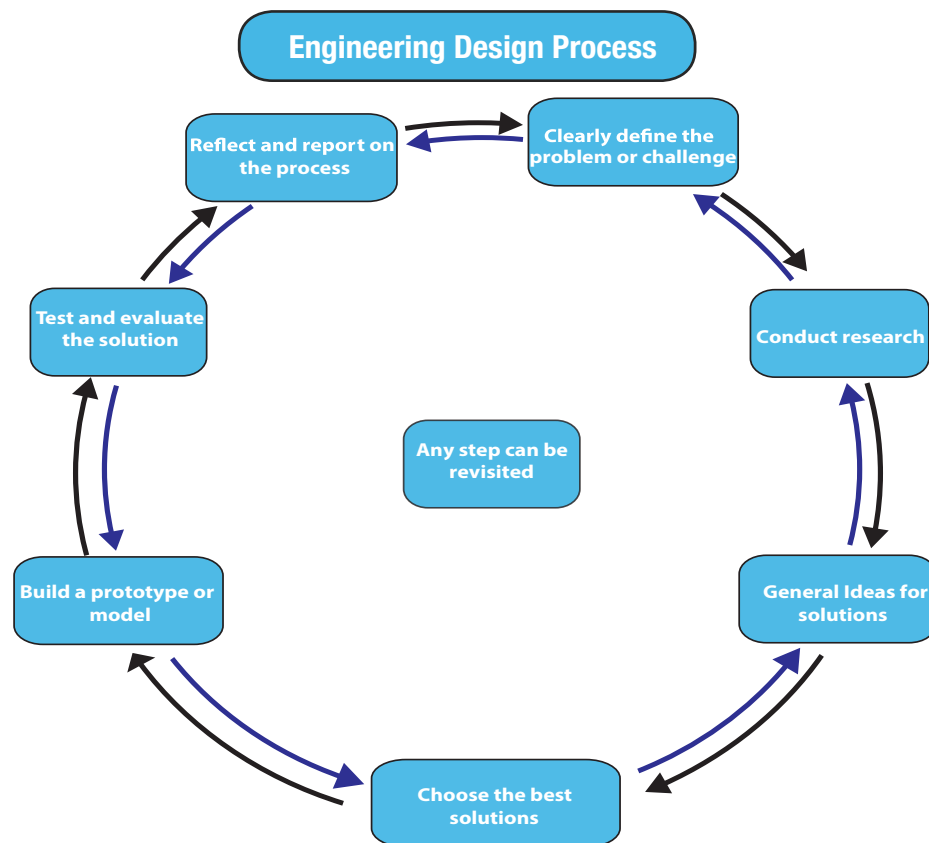
Trial and Error

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

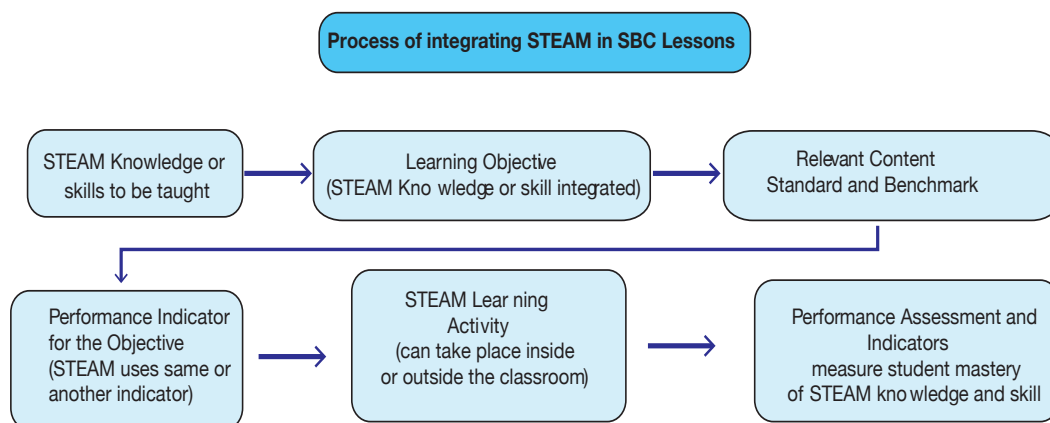
Effective STEAM lesson planning is key to the achievement of expected STEAM outcomes. STEAM skills can be planned and taught using separate STEAM-based lesson plans or integrated into the standards-based lesson plans. To effectively do this, teachers should know how to write effective standards and STEAM-based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

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)

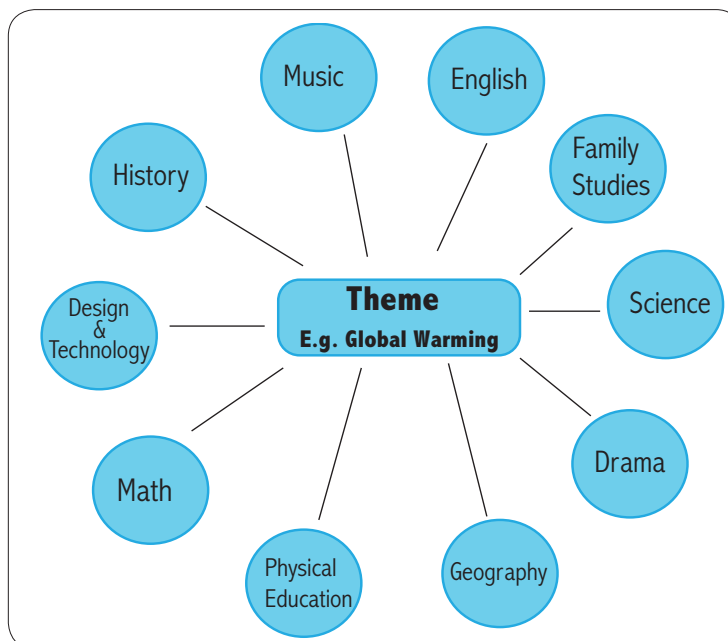
Teachers must develop intriguing curriculum by going beyond the traditional teaching of content based or fragmented teaching to one who is knowledge based and who should be perceived as a 21st Century innovative educator. Curriculum integration is a holistic approach to learning thus curriculum integration 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

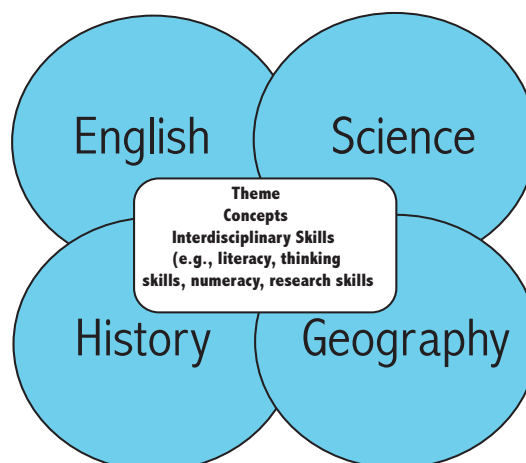
In this approach learning involves a theme or concept that will be taught right across all subject area of study by students. That is, content of a particular theme will be taught right across all subjects as shown in the diagram below. For instance, if the theme is global warming, subject areas create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



1. (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. Intradisciplinary 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.

Below are the three steps to planning project based curriculum.

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 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

SUBJECT AREAS

Theme

Concepts

Life Skills

Real world Context -
(Voluntary services/Part time
job experience, exchange programs)

Students Questions

These integrated learning approaches will demand for teachers 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;

- | | |
|--|--|
| <ul style="list-style-type: none"> • Public and private (privileged) knowledge • Specialised knowledge • Good and bad knowledge • Concepts, processes, ideas, skills, values, attitudes • Theory and practice • Fiction and non-fiction • Traditional, modern, and postmodern knowledge | <ul style="list-style-type: none"> • Subject and discipline-based knowledge • Lived experiences • Evidence and assumptions • Ethics and Morales • Belief systems • Facts and opinions • Wisdom • Research evidence and findings • Solutions to problems |
|--|--|

Types of Processes

There are different types of processes. These include;

- | | |
|---|---|
| <ul style="list-style-type: none"> • Problem-solving • Logical reasoning • Decision-making • Reflection | <ul style="list-style-type: none"> • Cyclic processes • Mapping (e.g. concept mapping) • Modelling • Simulating |
|---|---|

Science Inquiry processes include:

- Gathering information
- Analysing information
- Evaluating information
- Making judgements
- 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

<p>A person who thinks critically always evaluates an idea in a systematic manner before accepting or rejecting it. Critical thinking skills include;</p>	
<ul style="list-style-type: none"> • Attributing • Comparing and contrasting • Grouping and classifying • Sequencing • Prioritising • Analysing 	<ul style="list-style-type: none"> • Detecting bias • Evaluating • Metacognition (Thinking about thinking) • Making informed conclusions.

ii Creative Thinking Skills

<p>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;</p>	
<ul style="list-style-type: none"> • Generating ideas • Deconstruction and reconstruction • Relating • Making inferences • Predicting • Making generalisations • Visualizing 	<ul style="list-style-type: none"> • Synthesising • Making hypothesis • Making analogies • Invention • Transformation • Modeling • 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

<ul style="list-style-type: none"> • Listens, read, write, and speak with comprehension and clarity • Define and apply discipline-based conceptual vocabulary • Describe people, places, and events, and the connections between and among them • Arrange events in chronological sequence • Differentiate fact from opinion • Determine an author's purpose • Determine and analyse similarities and differences • Analyse cause and effect relationships • Explore complex patterns, interactions and relationships • Differentiate between and among various options 	<ul style="list-style-type: none"> • Listens, read, write, and speak with comprehension and clarity • Define and apply discipline-based conceptual vocabulary • Describe people, places, and events, and the connections between and among them • Arrange events in chronological sequence • Differentiate fact from opinion • Determine an author's purpose • Determine and analyse similarities and differences • Analyse cause and effect relationships • Develop an ability to use and apply abstract principals • Explore and/or observe, identify, and analyse how individuals and/or societies relate to one another
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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	

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.

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
<ul style="list-style-type: none"> • Sanctity of life • Truth • Aesthetics • Honesty • Human • Dignity • Rationality • Creativity • Courage • Liberty • Affectivity • Individuality 	<ul style="list-style-type: none"> • Self-esteem • Self-reflection • Self-discipline • Self-cultivation • Principal morality • Self-determination • Openness • Independence • Simplicity • Integrity • Enterprise • Sensitivity • Modesty • Perseverance

2. Social Values

Core Values	Sustaining Values
<ul style="list-style-type: none"> • Equality • Kindness • Benevolence • Love • Freedom • Common good • Mutuality • Justice • Trust • Interdependence • Sustainability • Betterment of human kind • Empowerment 	<ul style="list-style-type: none"> • Plurality • Due process of law • Democracy • Freedom and liberty • Common will • Patriotism • Tolerance • Gender equity and social inclusion • Equal opportunities • Culture and civilisation • Heritage • Human rights and responsibilities • Rationality • Sense of belonging • Solidarity • Peace and harmony • Safe and peaceful communities

Types of Attitudes

Attitudes - Ways of thinking and behaving, points of view

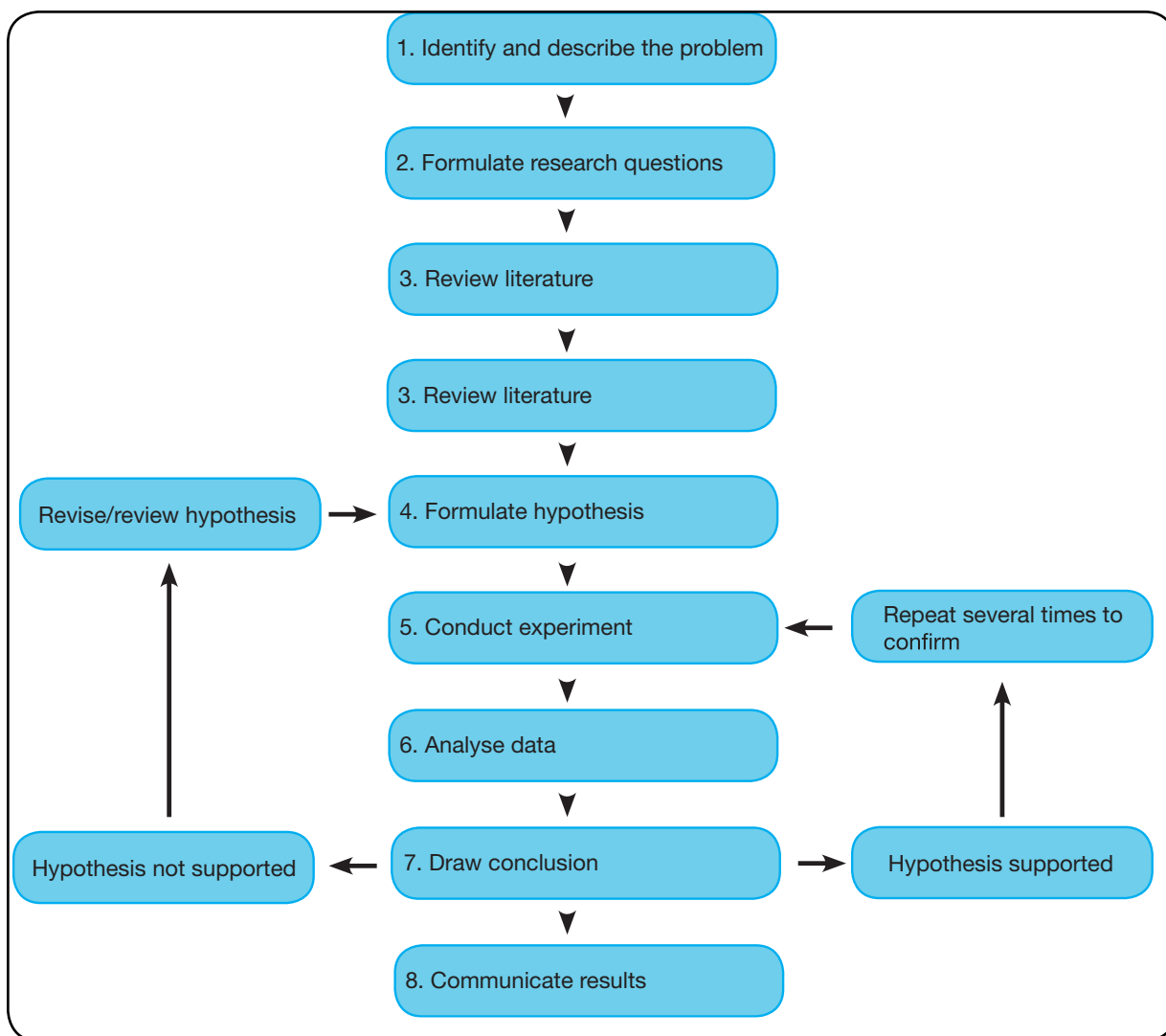
- | | |
|---|---|
| <ul style="list-style-type: none"> • Optimistic • Participatory • Critical • Creative • Appreciative • Empathetic • Caring and concern • Positive • Confident • Cooperative | <ul style="list-style-type: none"> • Responsible • Adaptable to change • Open-minded • Diligent • With a desire to learn • 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: Valid Hypothesis

- The flashlight did not produce light without batteries. The flashlight did produce light when batteries were inserted.

Therefore, the hypothesis that batteries give the flashlight energy to produce light is valid, given that no changes are made to the flashlight during the experiment.

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 Used to extend students' understanding 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 presentations. This enriches the students' existing knowledge of the topic.
DEBATE 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. 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. They are engaged in collaborative learning by delegating and sharing tasks to group members. When debating, they improve their communication skills.

<p>DISCUSSION The purpose of discussion is to educate students about the process of group thinking and collective decision.</p>	<p>The teacher opens a discussion on certain topic by asking essential questions. During the discussion, the teacher reinforces and emphasises on important points from students responses. Teacher guide the direction to motivate students to explore the topic in greater depth and the topic in more detail. Use how and why follow-up questions to guide the discussion toward the objective of helping students understand the subject and summarise main ideas.</p>	<p>Students ponder over the question and answer by providing ideas, experiences and examples. Students participate in the discussion by exchanging ideas with others.</p>
<p>GAMES AND SIMULATIONS Encourages motivation and creates a spirit of competition and challenge to enhance learning</p>	<p>Being creative and select appropriate games for the topic of the lesson. Give clear instructions and guidelines. The game selected must be fun and build a competitive spirit to score more than their peers to win small prizes.</p>	<p>Go into groups and organize. Follow the instructions and play to win</p>
<p>OBSERVATION Method used to allow students to work independently to discover why and how things happen as the way they are. It builds curiosity.</p>	<p>Give instructions and monitor every activity students do</p>	<p>Students possess instinct of curiosity and are curious to see the things for themselves and particularly those things which exist around them. A thing observed and a fact discovered by the child for himself becomes a part of mental life of the child. It is certainly more valuable to him than the same fact or facts learnt from the teacher or a book. Students Observe and ask essential questions Record Interpret</p>
<p>PEER TEACHING & LEARNING (power point presentations, pair learning) Students teach each other using different ways to learn from each other. It encourages; team work, develops confidence, feel free to ask questions, improves communication skills and most importantly develop the spirit of inquiry.</p>	<p>Distribute topics to groups to research and teach others in the classroom. Go through the basics of how to present their peer teaching.</p>	<p>Go into their established working groups. Develop a plan for the topic. Each group member is allocated a task to work on. Research and collect information about the topic allocated to the group. Outline the important points from the research and present their findings in class.</p>

<p>PERFORMANCE-RELATED TASKS (dramatization, song/lyrics, wall magazines) Encourages creativity and take on the overarching ideas of the topic and are able to recall them at a later date</p>	<p>Students are given the opportunity to perform the using the main ideas of a topic. Provide the guidelines, expectations and the set criteria</p>	<p>Go into their established working groups. Being creative and create dramas, songs/lyrics or wall magazines in line with the topic.</p>
<p>PROJECT (individual/group) Helps students complete tasks individually or collectively</p>	<p>Teacher outline the steps and procedures of how to do and the criteria</p>	<p>Students are involved in investigations and finding solutions to problems to real life experiences. They carry out researches to analyse the causes and effects of problems to provide achievable solutions. Students carefully utilise the problem-solving approach to complete projects.</p>
<p>USE MEDIA & TECHNOLOGY to teach and generate engagement depending on the age of the students</p>	<p>Show a full movie, an animated one, a few episodes form documentaries, you tube movies and others depending on the lesson. Provide questions for students to answer before viewing</p>	<p>Viewing can provoke questions, debates, critical thinking, emotion and reaction. After viewing, students engage in critical thinking and debate</p>

Strands, Units and Topics

This section of the teacher guide contains the Chemistry content to be taught in grade 12. It consists of;

- a brief explanation of how the topics, learning objectives and lesson topics are derived.
- an overview of the content distributed according to the four terms in an academic year;
- the unit of work per strand

Chemistry is organized around two main strands – Science as Inquiry and Physical Science. These strands embed the content that students are expected to learn and master at each grade and school level. National content standards are benchmarked at each grade level, which allows for essential KSAV's to be reinforced and expanded throughout the grades. Benchmarks show grade level expectations of what students are able to do to demonstrate that they are making progress towards attaining the content standard.

Grade-level benchmarks are unpacked to identify the topics, learning objectives and KSVAs.

Identifying topics from benchmarks

In order to identify the topic from the benchmark, the benchmark needs to be unpacked. When unpacking a benchmark, identify what students will be able to know and do in order to master the benchmark.

1. Write out the benchmark that you want to unpack.
2. Write the verbs (skills/actions) – Higher order thinking skills
3. Underline or highlight the big idea (content) in the benchmark. The big idea (content) is the topic derived from the benchmark.
4. Write essential questions that would be engaging for students
5. Develop sub-topics from the big idea (topic)
6. Write learning objectives according to the sub-topics
7. Write lesson topics from the learning objectives

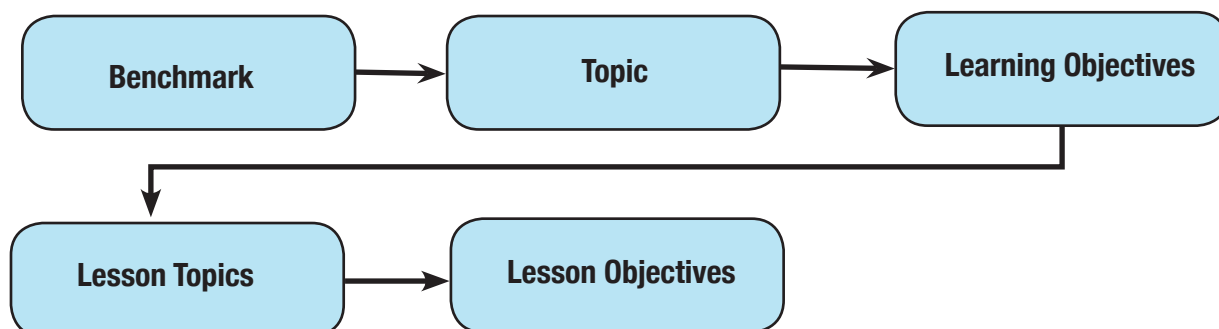


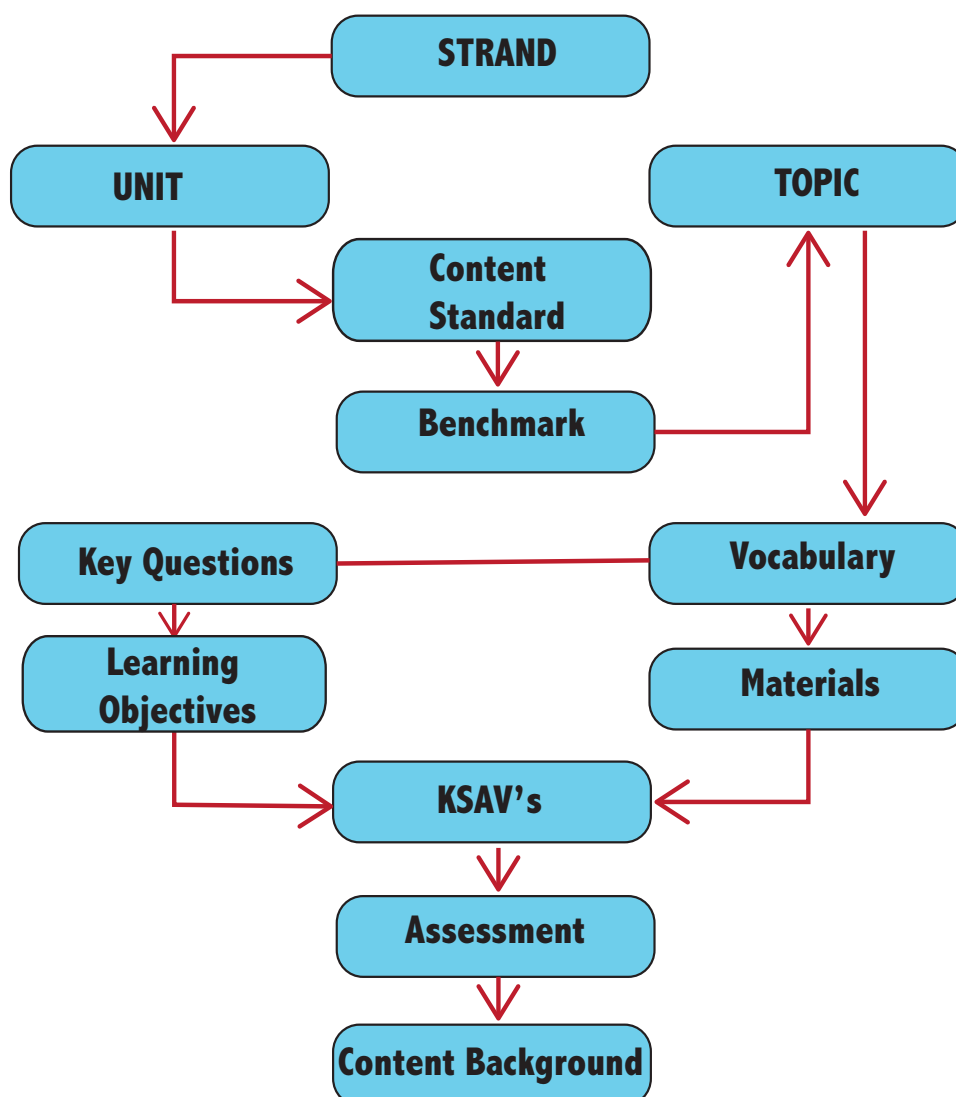
Table of strand, units and topics

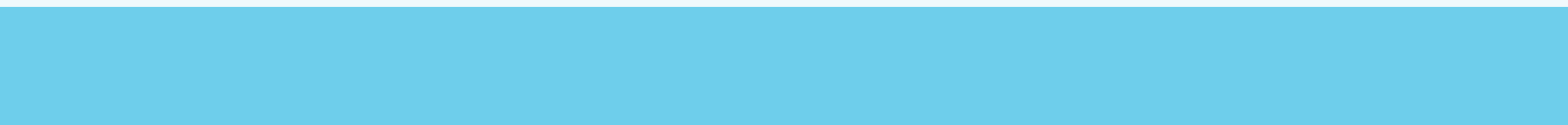
The table below outlines the contents of Grade 11 Chemistry in strands, units, topics and with the suggested lesson titles to be in an academic year. Teachers are provided with what will be taught under each of the four strands in a year. This overview will guide the teachers on how to plan their teaching programs for a school year in each term.

Strands	Units	Topics	Suggested Lesson Titles
Science as Inquiry	Quantities and Measurement	Quantities and Units	Traditional Measurement Systems & Physical Quantities
			Standard and Derived SI Units
			Unit Conversions
			Physical Quantities: Definition and Examples
		Dimensions, Significant Numbers and Scientific Notations	Dimensions
			Significant Figures
			Scientific Notations
			Order of Magnitude
		Error Analysis	Types of Errors and their definitions
			Uncertainties, Minimizing Errors
		Measuring Instruments	Measuring Instruments and their uses. Example: Timer, Thermometer, Measuring Cylinder, Balance, Vernier Caliper, Micrometer Screw Gauge
		Graphical Representations of Data and Information	Graphs (Dependent and Independent variable) and lines of best fit
			Linear and Direct Relationships
			Quadratic and Inverse Relationships
		Scalars and Vectors	Scalars and Vectors – Definition and Types
			Vector Addition, Subtraction, Multiplication (Geometric Approach)
			Vector Representation and Components
			Vector Resolution
The Dot Product and Vectors: Definition, Formula and calculations			
Physical Science	Kinematics (Motion)	Objects in Motion	What is Kinematics? - Studying the Motion of Objects
			What is Position in Physics? - Definition & Examples
		Characteristics of Motion	Distance and Displacement in Physics: Definition and Examples
			Speed and Velocity: Difference and Examples
			Acceleration: Definition, Equation and Examples
			Uniformly-Accelerated Motion and the Five Motion Equations
			Describing Motion
		Ticker Tape Diagrams: Analyzing Motion and Acceleration	
		Using Position vs. Time Graphs to Describe Motion	
		Determining Slope for Position vs. Time Graphs	
		Using Velocity vs. Time Graphs to Describe Motion	
		Determining Acceleration Using the Slope of a Velocity vs. Time Graph	
		Velocity vs. Time: Determining Displacement of an Object	
		Understanding Graphs of Motion: Giving Qualitative Descriptions	
		Free Fall	Free Fall Physics Practice Problems
			Graphing Free Fall Motion: Showing Acceleration
		Projectile Motion	The Acceleration of Gravity: Definition & Formula
			Projectile Motion: Definition and Examples
	Projectile Motion Practice Problems		
	Dynamics (Force and Motion)	Force	Force: Definition, unit and Types
			Forces: Balanced and Unbalanced (Net force)
			Force: Friction (definition)
			Static and kinetic friction
Coefficient of friction			

			Drawing structures for covalent and coordinate bonds	
			Polar Molecules	
		Chemical Reactions	Synthesis, combination and decomposition reactions	
			Ionic equations	
			Neutralization reactions	
			Displacement reactions	
			Precipitation reactions	
			Oxidation-Reduction (Redox) reactions	
		Inorganic Compounds	Naming rules for inorganic compounds	
			Applying the naming rules for inorganic compounds	
			Complex ions	
			Complex ions	
			Naming rules for complex ions	
		Analytical Chemistry	Separation of Impure Substances	Decantation and Filtration
				Boiling Point Elevation and Melting Point Depression

In this section, the content is arranged into topics, benchmarks together with the essential, knowledge, skills, attitudes and values. Learning objectives are provided for each topic in the units for the teacher to utilize in developing their lesson objectives.





Grade 11 Chemistry

Teaching Content

Strand 1: Physical Science

Topic: Introduction to Chemistry

Content Standard 11.2.1

Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.

Benchmark 1.2.1.1

Distinguish between pure and impure substances.

Key question(s):

1. What are pure and impure substances?
2. How are elements different from compounds?
3. How are homogeneous mixtures different from heterogeneous mixtures?

Vocabulary:

Matter, Pure substances, impure substances, mixtures, elements, compounds, homogenous, heterogeneous.

Learning

- Classify substances as pure or impure.
- Differentiate between elements and compounds
- Differentiate between homogeneous and heterogeneous mixtures.

Materials:

Samples of:

- Elements
- Compounds
- Mixtures (homogeneous and heterogeneous)

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Types of substances • Definitions of terms used in Chemistry 	<ul style="list-style-type: none"> • Applying definitions and classification process 	<ul style="list-style-type: none"> • Appreciate the different types of substances that compose matter.

Assessment

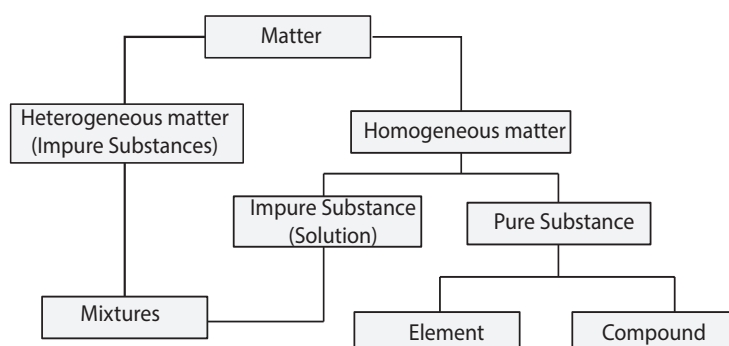
- Investigate and explain the difference in compositions of pure and impure substances.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background**Nature of Matter****Classifying substances**

All matter can be classified as either pure or impure.

Elements and compounds are classified as pure substances. Mixtures are impure substances. The following diagram summarizes the classification of the different types of matter.



Pure Substances

Element

An element is the simplest unit of matter. Each element has unique physical and chemical properties. A sample of lead has its own color, density, melting and boiling point. These properties of lead are different from those of another element such as gold.

Elements mostly exist as single atoms; however, elements may also exist as molecules. For instance: iron consists of single iron atoms. Oxygen on the other hand consists of two atoms chemically bonded together to form a molecule of oxygen, O_2 .

Elements are often represented by writing their chemical symbols which are found in the periodic table. Thus, iron is Fe, while oxygen is written as O.

Compound

A compound is a substance that contains two or more different elements that are chemically combined. Compounds have properties that are very different to its parent elements.

One main aspect of compounds is that it is made of masses of elements combined in a fixed ratio. The number of atoms in elements is also present in a fixed ratio. For example: Water is a compound of hydrogen and oxygen. Although Hydrogen and Oxygen exist as gases at room temperature, water exists as a liquid. Each molecule of water consists of 2 atoms of hydrogen and one atom of oxygen bonded together. Any mass of pure water can be expected to contain 2 parts of hydrogen to 1 part of oxygen.

Compounds are formed by chemical reactions between parent atoms. Thus only a chemical change can cause the compound to change back to its parent elements.

Compounds are represented by chemical formulas which are combinations of element symbols found on the periodic table. Water has the chemical formula H_2O , to illustrate the ratios of atoms that it is composed of.

Impure Substances

Mixture

A mixture is composed of one or more element or compound that are physically mixed but not chemically combined. There are two types of mixtures; heterogeneous mixture and homogenous mixtures.

Heterogeneous mixtures

Heterogeneous mixtures have non-uniform composition. They exist in more than one phase. Suppose we have two substances A and B in a heterogeneous mixture. If we draw two samples of the mixture, we may find that one sample has 50% of substance A while the other sample has 30% of substance A. That is different samples of the mixture will contain varying amounts of substance A.

An example of a heterogeneous mixture is rocks which can contain varying amounts of minerals.

Homogeneous mixtures

Homogeneous mixtures have uniform composition.

Suppose we have two substances A and B in a homogeneous mixture. If we again draw two samples of the mixture, we will find that one sample contains 50% of sample A while the other sample also has 50%. In homogeneous mixtures the composition is the same.

Many mixtures are homogeneous in nature such as solutions of ionic compounds.

Unit: Inorganic Chemistry**Topic : Atoms and the Periodic****Content Standard 11.2.1**

Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.

Benchmark 11.2.1.2

Examine the properties of a substance as a consequence of its physical state and chemical composition.

Key question(s):

1. What are the main parts and particles in an atom?
2. What are atomic shells and subshells?
3. How do we write electron configurations using subshells?

Vocabulary

Protons, neutrons, electrons, nucleus, electron shells, atoms, ions, anions, cations.

Learning Objectives (s)

By the end of the topic, students can:

- Describe the general features of an atom.
- Determine electron configurations for atoms and ions.

Materials

Atomic models

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Main features of atoms and ions • Concept of shells and subshells • Expressing electron configurations for atoms and ions 	<ul style="list-style-type: none"> • Applying theoretical models. • Making deductions and inferences from given data. 	<ul style="list-style-type: none"> • Appreciate the significance of atomic models in explaining the structure of matter.

Assessment

- Analyse and construct electron shell diagrams to show the arrangement of electrons on shells for atoms and ions.
- Write the electron configuration of elements using sub-shell notation (s, p, d, f).

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background**Atoms**

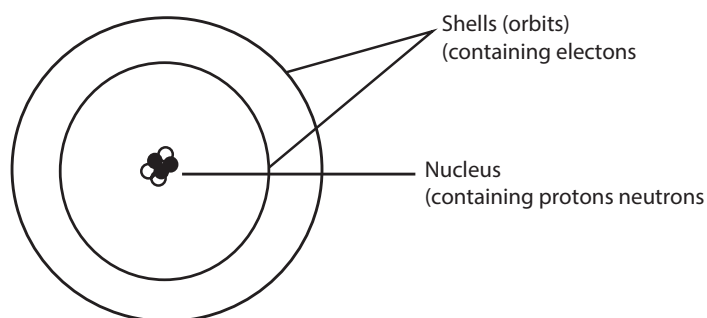
Atoms are the simplest unit of matter. The idea of matter existed in Science for many centuries, but it was formally introduced by John Dalton in the 19th Century. Dalton's hypothesis on atoms is summarized in three crucial statements.

1. Elements are made up of tiny particles called atoms. All the atoms of a given element are identical having the same physical and chemical properties.
2. Compounds are made up of atoms from one or more elements. The ratio of component atoms in a compound is always constant.

3. Chemical reactions only result in separating, combining or rearranging atoms. That is, in any chemical reaction, no atoms are destroyed or no new atoms are made.

Atomic Structure

- Atoms contain a nucleus and shells (orbitals).
- The main constituents of atoms are the sub-atomic particles, namely, protons, neutrons and electrons.
- A typical atom has a radius of approximately $1 \times 10^{-10}\text{m}$.
- Atoms are mostly composed of empty space.



Sub-atomic particles

There are three main sub-atomic particles. The properties of these particles are summarized in the table below.

Particle	Where it is found	Relative Mass	Charge unit
Proton	Nucleus	1	+1
Neutron	Nucleus	1	0
Electron	Orbitals (shells)	1/1840	-1

Nucleus

- The nucleus consists of protons and neutrons.
- It occupies a space of about $5 \times 10^{-15}\text{m}$. This means that the nucleus is about 10 000 times smaller than an atom.
- The nucleus consists of about 99.9% of the mass of atom.

Atomic shells and subshells

Electrons are found in shells (orbitals) surrounding the nucleus of an atom. Electron configuration shows the short hand representation of drawing electron shell diagrams.

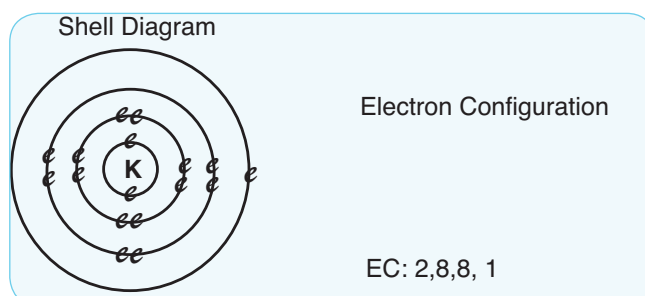


Figure: Shows the electron shell diagram and electron configuration (EC) for a Potassium atom.

Unit : Inorganic Chemistry

Topic : Periodic Table

Content Standard 11.2.1

Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.

Benchmark 11.2.1.2

Analyse trends and explain the arrangement of elements in the periodic table.

Key question(s):

1. How are elements arranged on the periodic table?
2. What are isotopes?
3. What is common for elements in the same group?
4. What is common about elements in the same period?

Vocabulary

Mass Number (A), Atomic Number (Z) Isotopes

Learning Objectives (s)

By the end of the topic, students can:

- Describe the features and organization of the periodic table.
- Distinguish between atoms, elements and isotopes.
- Explain the relationships in the properties of elements with the same group or period.

Materials

Periodic Table of Elements

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Features of the periodic table. • Definitions of terms used in Chemistry 	<ul style="list-style-type: none"> • Applying theoretical models. • Interpreting and describing tables and graphical information. 	<ul style="list-style-type: none"> • Appreciate the significance of the periodic table in classifying and organizing elements.

Assessment

- Investigate and explain why elements in the same group behave similarly.
- Describe the relationship between group number and period number and draw electron shell diagrams.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

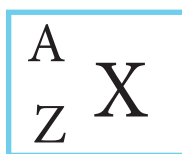
Periodic Table

The periodic table is an important tool in chemistry.

- It is an organization of chemical elements based on their atomic numbers and mass numbers.
- It shows how elements can be classified into groups according to similar chemical properties.
- It also allows us to predict or make inferences on some properties of elements and their compounds.

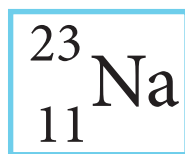
Reading element symbols

Elements on the periodic table often appear as shown in the general form below.



- The atomic number of the element is given as a sub-script (Z).
- The atomic mass number of the element is given as a super-script (A)
- The element's chemical symbol is X for element X .

Example: Below is the element symbol for sodium from the periodic table.



This symbol tells us that sodium has an atomic number of 11, an atomic mass of 23 and the chemical symbol Na .

Atomic number (Z)

- The atomic number is unique for each element.
- It gives us the number of protons that are found in the nucleus of the atom.
- The higher the atomic number, the more protons the atom has and the heavier the atom becomes.
- The atomic number also indicates the number of electrons found in a neutral sodium atom.

$$N = A - Z$$

Sodium has an atomic number of $Z = 11$. This means that any sodium atom has eleven protons in its nucleus. It also implies that there are 11 electrons in a neutral sodium atom.

Mass number (A)

$$N = 23 - 11 = 12$$

The mass number (atomic mass number) gives the number of protons and neutrons found in the nucleus of an atom.

Atoms with high mass numbers have numerous protons and neutrons in their nucleus. The mass number can be used to find out how many neutrons (N) and there are in the nucleus of an atom.

Sodium has an atomic number $Z = 11$ and atomic mass number $A = 23$. The number of neutrons in a sodium atom is: " $N=23-11=12$ "

There are 12 neutrons in a sodium atom.

- Most heavy elements have large nuclei (plural for nucleus) which often become unstable. These heavy unstable nuclei often break up. The disintegration of heavy unstable nuclei is called **radioactivity**.

Isotopes

- Isotopes are atoms of an element that have the same atomic number, but have different mass numbers.
- That is isotopes differ in the number of neutrons found in the nucleus.
- Most elements have one or more isotopes.
- Hydrogen has three isotopes, namely hydrogen (${}^1_1\text{H}$), deuterium (${}^2_1\text{H}$), and tritium (${}^3_1\text{H}$). The first isotope has 1 proton and no neutrons. The second isotope has 1 proton and 1 neutron, while the third isotope has 1 proton and 2 neutrons.
- Except for hydrogen, all isotopes are named using their mass numbers.
- Chemical changes involving atoms, depend mostly on protons and electrons. Thus, isotopes have the same chemical properties as all other atoms of an element.

1A																	8A
1	2A											3A	4A	5A	6A	7A	2
1 H												5 B	6 C	7 N	8 O	9 F	10 Ne
3 Li	4 Be											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
11 Na	12 Mg	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt									
57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu			
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr			

	Metals
	Metalic
	Non-metals

- Atomic numbers increase as we move from left to right. As we move from top to bottom, atomic numbers also increase.
- All elements can be classified as metals, non-metals or metalloids. With the exception of hydrogen, metals are found on the left, while elements with non-metallic properties are found on the right. In between these two groups we have the metalloids.
- Groups on the periodic table refer to the vertical columns of elements. There are 18 groups on the periodic table. These groups are numbered from 1A to 8A and 1B to 8B. Groups 1B to 8B are transition metals.
- Elements in the same group are often referred to as families. The elements are not identical but behave in the same way.
- Periods on the periodic table refer to the horizontal rows of elements. Some properties of elements change gradually as we move from left to right across a period.

Unit: Inorganic Chemistry

Topic: Mole Concept

Content Standard 11.2.1

Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.

Benchmark 11.2.1.4

Explain the mole concept and the relationship between Relative Atomic Mass and isotopes.

Key question(s):

- What is Avogadro's number and what does it tell us?
- What does 1 mole of an element or a compound mean?

Vocabulary

Relative Atomic Mass (RAM), Relative Isotopic Mass (RIM), Mole (n), Molar Mass (Mr)

Learning Objectives (s)

By the end of the topic, students can:

- Explain the relationship between Avogadro's number and the mole concept.
- Determine the number of moles of a given mass of element or compound.

Materials

Periodic table, Electronic weighing balance

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Avogadro's Number • Mole concept • Relationship between Avogadro's number and the mole concept • Molar mass 	<ul style="list-style-type: none"> • Mathematical skills for calculations. • Interpreting and describing tables and graphical information. 	<ul style="list-style-type: none"> • Appreciate the mole concept and the relationship with Avogadro's number. • Appreciate the role of mathematics in quantitatively describing matter.

Assessment

- Apply Avogadro's law and calculate the moles (n) of a substance given mass and number of particles.
- Determine the molar mass (Mr) of given elements and compounds.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Mole Concept

Mole (n) is defined as the amount of substance or chemical quantity that contains as many atoms, molecules, ions or electrons as there are in exactly 12 grams of carbon-12.

Mole, symbol 'mol' can also be defined as a unit which represents 6.02×10^{23} particles of a substance. 6.02×10^{23} is known as the Avogadro's number and is symbolized N_A . It is named after the scientist Amedeo Avogadro. This constant can be used to determine amount of substance in mols as well as chemical quantity by mass in grams.

$$\text{Avogadro's number } (N_A) = \frac{\text{Number of Particles } (N)}{\text{amount of substance in moles } (n)}$$

Note: According to Avogadro's law, 1 mole of any given substance will contain the same number of particles.

$$\text{Thus, } n = \frac{N}{N_A} \quad \text{where, } N_A = 6.02 \times 10^{23} \text{ particles}$$

Example:

Calculate the amount in mols of 1.204×10^{23} ions of iron.

$$n = \frac{N}{N_A}$$

$$n = \frac{1.204 \times 10^{23}}{6.02 \times 10^{23}} = 0.2 \text{ mols}$$

Molar mass M_r is the mass of one mol of any given substance, atoms, ions, molecule or compound. For a compound molar mass is calculated by adding up the mass of elements present in it. Moles of substances can also be calculated using given mass in grams and calculated molar mass.

Example:

Calculate the amount in mols of 20 grams of NaCl .

$$\text{moles } (n) = \frac{\text{Mass in grams of substance}}{\text{Molar mass of substance}}$$

$$\text{moles } (n) \text{ of } \text{NaCl} = \frac{20\text{g}}{58.5\text{g/mol}} = 0.34\text{mols}$$

Unit : Inorganic Chemistry

Topic : Metals and Non-Metals

Content Standard 11.2.1

Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.

Benchmark 11.2.1.5

Determine electron configurations and illustrate the structures of atoms, ions and compounds.

Key question(s):

1. What are the properties of metals, metalloids and non-metals?
2. What are the elemental properties of nitrogen and sulfur?
3. What are some of the common compounds made from nitrogen and sulfur?

Vocabulary

Metals, non-metals, metalloids, acid rain, alloys, allotropes.

Learning Objectives (s)

By the end of the topic, students can:

- Describe the common properties of metals, metalloids and non-metals.
- Describe common compounds of nitrogen and sulfur.
- Explain the uses of common compounds of nitrogen and sulfur.

Materials

Metal and non-metal objects, periodic table.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Periodic table of elements • Names and chemical formulae of elements and compounds. • General properties and uses of metals, metalloids and non-metals. • Specific information relating to the significance of nitrogen, sulfur and their compounds. 	<ul style="list-style-type: none"> • Interpreting and describing tables and graphical information. • Comparing and contrasting physical and chemical properties of elements and compounds. 	<ul style="list-style-type: none"> • Appreciate the differences in chemical and physical properties of metals, metalloids and non-metals. • Recognise the importance of nitrogen and sulfur in the natural environment and industry.

Assessment

- Investigate and write chemical equations to show formation of nitrogen and sulfur compounds.
- Compare the reactivity of metals with different substances and write their balanced chemical equations.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Metals and Non-metals

Properties of Metals

Metals have fewer electrons on their valence shell and are found on the left hand side of the periodic table. Metallic properties decrease as you move across the periodic table. Metals have common physical properties, but react differently depending on their reactivity.

Reactivity of metals also differs with the nature of substances it is reacted with. *i.e.* cold water, steam, dilute acids, concentrated acids.

Transition Metals

Transition metals are also known as the d-block metals and are found in the middle of the periodic table. They usually form coloured solutions.

Metalloids

Metalloids have properties intermediate between metals and non-metals. They behave like metals in some reactions and non-metals in other reactions.

Non-metals

Generally found on the right hand side of the periodic table. They have more electrons on the valence shell and are mostly liquids and gases at room temperature and pressure.

Nitrogen and its compounds

Nitrogen is a non-metal found in group V of the periodic table. It comprises of 79 % of the earth's atmosphere and exists as a diatomic molecule N_2 in nature. One of its compounds is ammonia which is industrially manufactured through the Haber process.

Sulfur and its compounds

Sulfur is a non-metal that exists in different allotropic forms. Sulfur burns vigorously in air with a blue flame to produce sulfur dioxide SO_2 , a gas with a choking smell.

Combustion of fossil fuels (coal, diesel) also produces sulfur dioxide. Sulfur dioxide reacts with water vapor in the atmosphere to form sulfurous acid, known as acid rain.

Unit: Inorganic Chemistry**Topic: Trends in the Periodic Table****Content Standard 11.2.1**

Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.

Benchmark 11.2.1.6

Explain the types of chemical reactions and determine the formulae of substances using established rules and naming conventions.

Key question(s):

1. What are the general trends in the periodic table?
2. How do we use these general trends in the periodic table to explain the chemical or physical behavior of elements?

Vocabulary

Atomic radii, electronegativity, electropositivity, electron affinity, ionisation energy, nuclear charge,

Learning Objectives (s)

By the end of the topic, students can;

- Explain the general trends in the periodic table.
- Explain the behavior of atoms of elements using general trends from the periodic table.

Materials

Periodic table of elements, atomic models

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Periodic table of elements • Names and chemical formulae of elements and compounds. • General properties and uses of metals, metalloids and non-metals. • Classify arrangement of elements as metals and non-metals. 	<ul style="list-style-type: none"> • Interpreting and describing tables and graphical information. • Comparing and contrasting physical and chemical properties of elements and compounds. • Explain different trends in the periodic table. 	<ul style="list-style-type: none"> • Appreciate the organizational qualities of the periodic table. • Appreciate the chemical properties of elements.

Assessment

- Analyse and explain different periodic trends across the period and down the group.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

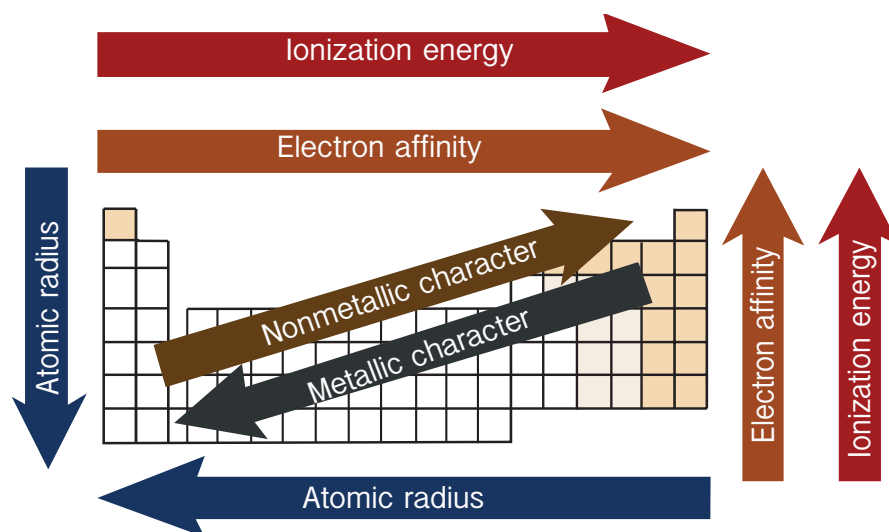
Content Background

Trends in the periodic table

The periodic table of elements is a regular arrangement of elements with similar chemical properties in vertical columns called groups. Horizontally they are arranged according to increasing atomic numbers in what is known as periods.

Periodic trends are specific patterns that are observed in the properties of the chemical elements. Major periodic trends include ionization energy, electron affinity, atomic radii, ionic radii, metallic and non-metallic character and chemical reactivity.

The diagram below shows the periodic trends.



Metallic and non-metallic properties

Reactivity of metals decreases across the period and increases down the group. This makes the group I, alkali metals to be the most reactive metals. Reactivity of metals are summarized by the table of reactivity series of metals.

Reactivity of non-metals increases across the period making the group VII elements (Halogens) to be the most reactive. Down the group, the reactivity of non-metals generally decreases.

Unit: Inorganic Chemistry**Topic : Chemical Bonding**

Content Standard 11.2.1	Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.
Benchmark 11.2.1.7	Explain the various chemical bonding models in relation to the properties and structures of chemical compounds.

Key question(s):

1. What are the general chemicals bonding models suggested by chemists?
2. How do these chemical bonds contribute to the properties of substances?
3. How can we represent structures of chemical compounds using diagrams?
4. What are polar molecules and how are they formed?
5. What is the significance of polar molecules?

Vocabulary

Covalent Bonding, Ionic Bonding, Metallic Bonding, Dative Bonding, Polar bonds, non-polar bonds, Octet rule, Duplet rule.

Learning Objectives (s)

By the end of the topic, students can:

- Describe the ionic, metallic, covalent and coordinate bonding models.
- Explain how the properties of compounds and elements are influenced by their type of bonding.
- Use the concept of polar molecules to explain the behavior of substances that contain polar molecules.

Materials

Molecular models, Periodic table.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Ionic bonding involves transfer of electrons from metal to non-metal. • Covalent bonding involves sharing of valence electrons between non-metals. • Metallic bonding involves a lattice of positive metal ions and a sea of mobile electrons. 	<ul style="list-style-type: none"> • Drawing simple diagrams to illustrate bonding between atoms, ions and molecules. • Comparing and contrasting chemical and physical properties of elements and compounds. • Draw outer shell diagrams to illustrate the bonding of elements and compounds. • Describe the concept of polar molecules. 	<ul style="list-style-type: none"> • Appreciate the different bonding models and how they can be used to explain the physical and chemical properties of elements and compounds.

Assessment

- Differentiate between bonding models and construct Lewis dot and cross diagrams to illustrate different types of bonding.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

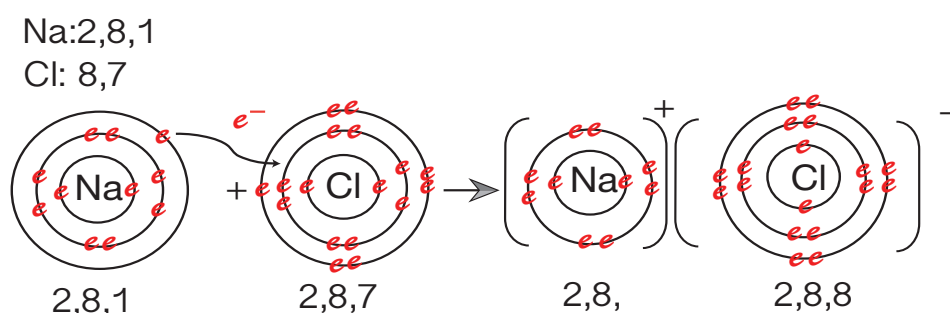
Content Background

In chemistry, chemical bonding describes the process of atoms joining together to form new substances. Lewis dot-cross diagrams are used to show atoms and molecules bonding. In all types of chemical bonding atoms try to achieve either the octet configuration (having eight electrons on the outermost shell to be stable) or the duplet configuration (having two electrons on the outermost shell to be stable). There are three (3) main types of bonding.

1. Ionic Bonding

Ionic bonding occurs between atoms of metals and non-metals through loss and gain of electrons. It is also known as an electrovalent bond. Resulting compounds are referred to as ionic compounds.

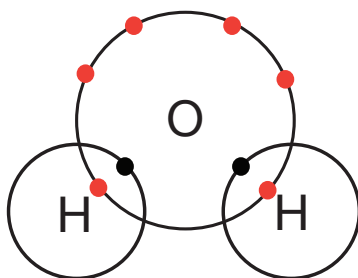
Example: Formation of Sodium Chloride



2. Covalent Bonding

Covalent bonding occurs between atoms of non-metals equally sharing electrons in their outer energy levels to form molecules.

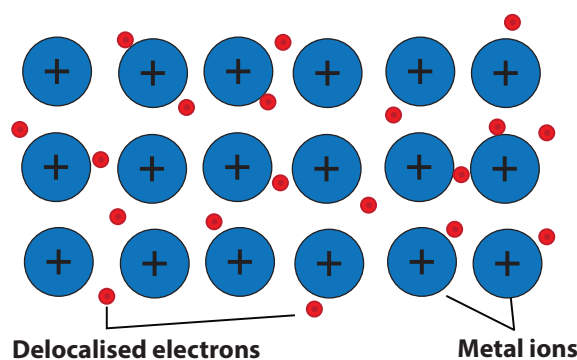
Formation of
water molecule (H_2O)



Coordinate covalent bond and **polar bond** are special types of covalent bonding. Coordinate covalent bond or dative bond refers to a covalent bond in which both electrons for pairing come from the same atom. Polar covalent bond is a type of chemical bond where a pair of electrons is unequally shared between two atoms because one atom spends more time with the electrons than the other atom. This results in the molecules having partial charges.

3. Metallic Bonding

Metallic bonding describes the strong electrostatic force of attraction between positive ions and the delocalized electrons that make up a metal.



Unit: Inorganic Chemistry

Topic: Inorganic Compounds

Content Standard 11.2.1	Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.
Benchmark 11.2.1.7	Explain the various chemical bonding models in relation to the properties and structures of chemical compounds.

Key question(s):

1. What are the features of the different types of chemical reactions?
2. What is the difference between ionic and net ionic equations?
3. How do we write balanced equations to represent chemical reactions?
4. What is the difference between Oxidation and Reduction?

Vocabulary:

Reactants, Products, Chemical Reaction, Chemical Equation, Physical Change, Chemical Change, State Symbols, Ionic Equation, Spectator ions.

Learning Objective(s)

By the end of the topic, students can:

- Describe the features of the types of chemical reactions.
- Produce balanced and appropriately structured chemical, ionic and net ionic equations to represent various types of chemical reactions.
- Differentiate between oxidation and reduction.

Materials

Laboratory chemicals, beakers, test tubes, thermometer, weighing balance.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Names and chemical formulae of elements, ions and chemical compounds • Rules for naming inorganic compounds • Chemical bonding models 	<ul style="list-style-type: none"> • Translating written or verbal names of chemical compounds into chemical formulae and vice versa. 	<ul style="list-style-type: none"> • Recognise the importance of following rules, processes and procedures to obtain intended outcomes. • Recognise the importance of scientific naming conventions.

Assessment

- Formulate balanced chemical equations including correct state symbols for the different reaction types.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

A compound is formed by at least two (2) elements chemically combined. For every compound, a chemical formula is written to represent it. The formula shows:

1. Types of atoms represented (elements)
2. Simple ratio of all atoms present

Chemical formula of ionic substances

To derive the correct chemical formula of an ionic compound, charges on the ions are used. When writing the chemical formula of ionic compounds, the chemical symbol of the metal is usually written first.

Example: the chemical formula for magnesium chloride



Note: The subscript 1 is usually omitted when writing the chemical formula.

Chemical formula of covalent compounds

For covalent compounds the name usually gives an indication of how many atoms of each element is present in the compound. For covalent compounds, common prefixes are used to indicate the number of atoms present in the formula.

Example: The chemical formula of carbon dioxide is CO_2 , which has one part carbon and two parts oxygen.

Common prefixes used in naming covalent compounds.

Prefix	Number of atoms
Mono	1
Di	2
Tri	3
Tetra	4
Penta	5

Unit : Inorganic Chemistry

Topic : Chemical Reactions

Content Standard 11.2.1	Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.
Benchmark 11.2.1.7	Explain the various chemical bonding models in relation to the properties and structures of chemical compounds.

Key question(s):

1. What are the rules for naming of an inorganic chemical compound from a chemical formula?
2. How can we determine the chemical formula of an inorganic compound from its chemical name?

Vocabulary:

Reactants. Products, Chemical Reaction, Chemical Equation, Physical Change, Chemical Change, State Symbols, Ionic Equation, Spectator ions.

Learning Objective(s)

By the end of the topic, students can:

- Distinguish between strong acid or base and weak acid or base.
- Explain dissociation of acids and bases.
- Write chemical equations and equilibrium expressions for acids and bases at equilibrium.
- Calculate dissociation constants for acids and bases.

Materials

Laboratory chemicals, beakers, test tubes, thermometer, weighing balance.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Names and chemical formulae of elements, ions and chemical compounds • Reactivity series • Rules and techniques in balancing chemical equations • Mole concept • Ionic and net ionic equations • Definitions of terms used in Chemistry. 	<ul style="list-style-type: none"> • Mathematical skills for calculations. • Applying rules for balancing chemical equations. • Translating written or verbal descriptions of chemical reactions into chemical equations. 	<ul style="list-style-type: none"> • Appreciate the role of chemical equations in concisely describing and summarising chemical reactions. • Appreciate the role of mathematics in quantitatively describing matter.

Assessment

- Formulate balanced chemical equations including correct state symbols for the different reaction types.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Chemical Reactions

Chemical reactions are results of chemical changes. Chemical reactions are represented by chemical equations. Every chemical equation is made up of reactants and products. Reactants are the substances that take part in the reaction and products are what are formed after the reaction is completed.

i.e. Reactants → Products

Chemical equations can be represented using word or symbol equations.

Word:	<i>Sodium</i>	+	<i>Chlorine</i>	→	<i>Sodium Chloride</i>
Symbol:	Na	+	Cl₂	→	NaCl

It is also important to ensure that the chemical equations are correctly balanced by having the same number of atoms on reactants and products side. A chemical equation is balanced by placing whole numbers as coefficients in front of chemical compounds or elements.

Example: $2\text{Na} + \text{Cl}_2 \longrightarrow 2\text{NaCl}$

Part of writing chemical equations is to assign correct state symbols. State symbols represent the state of matter reactants and products exist in. The state symbols are (s) solid, (l) liquid, (g) gas and (aq) aqueous.

Example: $2\text{Na (s)} + \text{Cl}_2 \text{(g)} \longrightarrow 2\text{NaCl (aq)}$

There are seven general types of reactions.

1. Combination or Synthesis Reaction
2. Decomposition Reaction
3. Neutralization Reaction
4. Displacement Reaction
5. Precipitation Reaction
6. Oxidation-reduction Reaction
7. Combustion Reaction

Unit: Inorganic Chemistry

Topic: Complex Ions

Content Standard 11.2.1 Students will be able to examine the properties of substances to distinguish between pure and impure substances in chemical bonding and reactions.

Benchmark 11.2.1.7 Explain the various chemical bonding models in relation to the properties and structures of chemical compounds.

Key question(s):

1. How can we determine the chemical formula of complex ions?
2. What features differentiate complex ions from simple ions?

Vocabulary:

Complex ions, Ligands, Coordination compounds, Coordination Number.

Learning Objective(s)

By the end of the topic, students can:

- Identify how complex ions form and name them correctly.
- Determine the chemical formula for complex ions.

Materials

Table of common ions and charges, Solubility table.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Name the chemical formula of elements, ions and chemical compounds. • Chemical Bonding • Common ions and their charges. 	<ul style="list-style-type: none"> • Apply rules to formulate formulae of complex ions. 	<ul style="list-style-type: none"> • Appreciate the importance of the application of rules in determining the formulae for complex ions.

Assessment

- Analyze and derive the chemical formulae of complex ions and name them.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background**Complex ion**

Complex ion is a metal ion with a Lewis base attached to it through coordinate covalent bonds. A complex compound also known as Coordination compound is a compound consisting either of complex ions with other ions or opposite charge or a neutral complex species.

Ligand

Lewis bases (electron pair donors) attached to the metal ion in a complex. Examples of common ligands include neutral water (H_2O), ammonia (NH_3), carbon monoxide (CO) and the anions cyanide (CN^-), chloride (Cl^-) and hydroxide (OH^-).

Coordination Number

Coordination number is the number of covalent bonds that the metal cation tends to form with the electron donor.

Example: $[\text{Fe}(\text{CN})_6]^{3-}$ ferricyanide

$[\text{Fe}(\text{CN})_6]^{4-}$ ferrocyanide

Unit : Analytical Chemistry

Topic : Separation of Impure Substances

Content Standard 11.2.2	Students will be able to investigate and use instruments and methods used to separate, identify and quantify matter.
Benchmark 11.2.2.1	Explain the methods of separating mixtures.

Key question(s):

1. How can we determine the chemical formula of complex ions?
2. What features differentiate complex ions from simple ions?

Vocabulary:

Melting point, Boiling Point, Miscible liquids.

Learning Objective(s)

By the end of the topic, students can:

- Compare different methods of separating mixtures.

Materials

Filter funnel, filter paper, distillation flask, separating funnel, desiccator, Buchner funnel, flasks, and beakers.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Types of mixtures • Methods of separating mixtures 	<ul style="list-style-type: none"> • Identifying types of mixtures. • Selecting appropriate separation methods. 	<ul style="list-style-type: none"> • Appreciate the differences in chemical and physical properties of substances • Appreciate the different methods of separating substances.

Assessment

- Investigate and analyze the efficiency of vacuum and gravity filtration.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background**Impure Substances****Mixture**

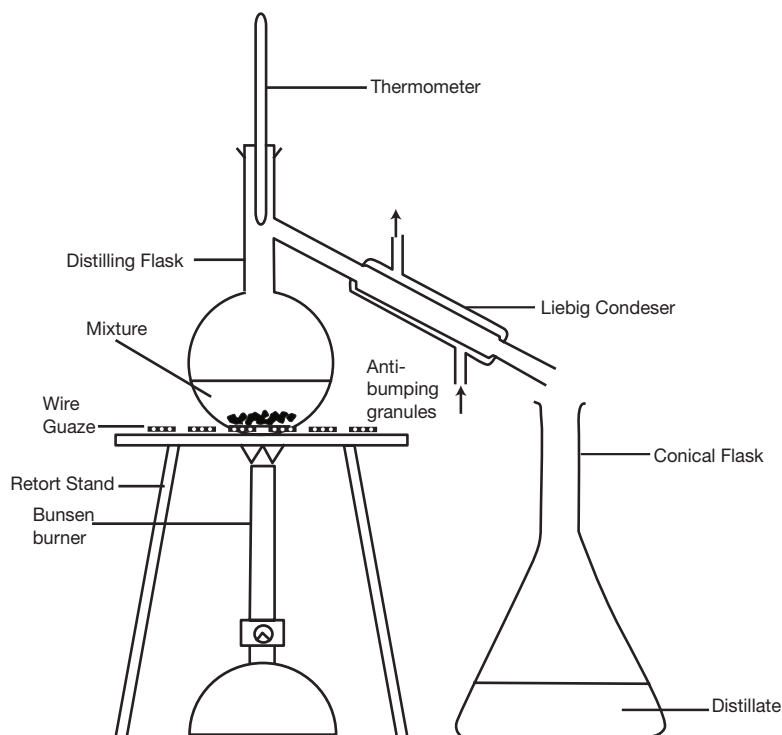
Not all substances exist as pure substances around us. Some exist as mixtures. A mixture is a substance that contains two or more substances that are not chemically combined. Example is the air we breathe in.

Mixtures can be separated into different components using physical separation techniques. It is important to determine purity of substances.

Purity of a substance can be determined by measuring its melting point and boiling point.

Example:

Alcohol and water are miscible (they mix well completely). They can however, be separated using distillation method due to their difference in boiling points. The mixture can be heated in a distillation flask until the temperature increases to 78°C and the alcohol distills over and is cooled in a Liebig condenser and collected. The remaining liquid continues to boil until then temperature is 100°C and water vaporizes.



There are two types of mixtures; heterogeneous mixture and homogenous mixtures.

Heterogeneous mixtures

Heterogeneous mixtures have non-uniform composition.

Suppose we have two substances A and B in a heterogeneous mixture. If we draw two samples of the mixture, we may find that one sample has 50% of substance A while the other sample has 30% of substance A. That is different samples of the mixture will contain varying amounts of substance A.

An example of a heterogeneous mixture is rocks which can contain varying amounts of minerals.

Homogeneous mixtures

Homogeneous mixtures have uniform composition.

Suppose we have two substances A and B in a homogeneous mixture. If we again draw two samples of the mixture, we will find that one sample contains 50% of sample A while the other sample also has 50%. In homogeneous mixtures the composition is the same.

Many mixtures are homogeneous in nature such as solutions of ionic compounds.

Unit : Analytical Chemistry

Topic : Identifying Pure Substances

Content Standard 11.2.2 Students will be able to investigate and use instruments and methods used to separate, identify and quantify matter.

Benchmark 11.2.2.1 Explain the methods of separating mixtures.

Key question(s):

1. How do qualitative methods of analysis help to identify substances?
2. How are chemical tests carried out?

Vocabulary:

Melting point depression, boiling point elevation, heating curve, cooling curve, emission spectrum, indicators.

Learning Objective(s)

By the end of the topic, students can:

- Interpret the outcomes of chemical identification tests.
- Explain how different chemical identification tests are carried out.
- Interpret the outcomes of chemical identification tests.
- Explain how different chemical identification tests are carried out.

Materials

Indicator
Samples of mixtures

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Names and chemical formula of elements and compounds. • Type and purpose of chemical tests 	<ul style="list-style-type: none"> • Observation of experiments. • Handling laboratory equipment 	<ul style="list-style-type: none"> • Recognise the importance of safety in science laboratory.

Assessment

- Investigate and explain the effects of impurities on the melting and boiling points of pure substances.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background**Pure Substances**

Pure substances exist in fixed proportion and are chemically combined.

Pure substances can be easily identified because they have fixed melting and boiling points. *i.e.* pure water will always boil at 100°C and melt at 0°C.

Addition of impurities to a pure substance directly affects their melting and boiling point and causes the melting point to decrease and boiling point to increase. Other techniques can also be used to determine the purity of a substance like the flame test.

A flame test is an analytical procedure used in chemistry to detect the presence of certain elements, primarily metal ions based on each elements emission spectrum.

Unknown solutions can be tested using indicators. Indicators are chemical substances that change colour to indicate the presence or absence of something. For example, litmus paper is an indicator which turns blue in alkaline solutions and red in acidic solutions.

Unit: Analytical Chemistry**Topic: Masses and Moles**

Content Standard 11.2.2 Students will be able to investigate and use instruments and methods used to separate, identify and quantify matter.

Benchmark 11.2.2.2 Determine molar masses of compounds and elements.

Key question(s):

How do quantitative methods of analysis help to identify substances?

Vocabulary:

Relative isotopic mass, Percentage abundance, Percentage Composition, Relative Molecular mass (RMM), Relative formula mass (RFM).

Learning Objective(s)

By the end of the topic, students can:

- Calculate molar masses of elements and compounds.
- Apply the mole concept to make quantitative conclusions.

Materials

Mass Spectrometre, Periodic Table, Weighing balance.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Mathematical skills in handling calculations. 	<ul style="list-style-type: none"> • Apply mathematical skills in handling calculations. 	<ul style="list-style-type: none"> • Appreciate the use of mathematics to communicate Chemistry knowledge

Assessment

- Investigate and explain the effects of impurities on the melting and boiling points of pure substances.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Mass is the measure of the amount of matter in an object and is usually measured in grams (g) or kilograms (kg). In chemical calculations, actual mass of atoms are used. Masses of different atoms are compared with the mass of carbon-12 (an isotope of carbon).

Thus the Relative Atomic Mass (RAM) of any atom is the number of times the mass of one atom of an element is greater than $1/12$ of the mass of one carbon-12 atom. Some relative atomic masses found in the periodic table are not whole numbers due to the naturally occurring isotopes with different percentage abundances.

The mole concept is used to determine chemical quantity. A mole (n) of a substance is defined as a mass of a substance containing the same numbers of fundamental units as there are atoms in exactly 12 g of carbon-12. Fundamental units may be atoms, molecules or formula units depending on the substance.

1 mole of substance = 6.02×10^{23} particles

Thus, $(n) = \frac{\text{Number of particles}}{\text{Avogadro's Constant}}$

$$(n) = \frac{N}{N_A}$$

Example: Determine the number of molecules (n) in 1.204×10^{22} atoms of lead.

$$(n) = \frac{N}{N_A} = \frac{1.204 \times 10^{22}}{6.02 \times 10^{23}} = 0.02 \quad \therefore n = 0.02 \text{ mol}$$

Moles can also be calculated using given mass (g) and molar mass (M_r), where molar mass is the mass of 1 mole of any substance.

$$\text{Moles } (n) = \frac{\text{mass in grams (g)}}{\text{molar mass (g/mol)}} \quad \text{i.e. } n = \frac{m}{M_r}$$

Example: Determine the moles of lead in 40 g of lead.

$$n = \frac{m}{M_r} = \frac{40\text{g}}{207\text{g/mol}} = 0.19 \quad \therefore n = 0.19\text{mols}$$

Unit: Physical Chemistry

Topic: Solutions and Solubility

Content Standard 11.2.3

Students will be able to investigate the physical structure of chemical compounds, the way they react with other matter and the bonds that hold their atoms together.

Benchmark 11.2.3.1

Determine the solubility of a substance and the concentration of a solution.

Key question(s):

1. What are the different types of solutions?
2. What factors affect solubilities of substances?

Vocabulary:

Solutions, solute, solvent, saturated solutions, unsaturated solutions, supersaturated solution, diffusion, concentration, vapour pressure.

Learning Objective(s)

By the end of the topic, students can:

- Identify different types of solutions and compositions.
- Determine factors that drive the formation of solutions.
- Apply the gas laws to make quantitative calculations and conclusions.

Materials

Beakers, test tubes, thermometer, Chemical solutions.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Types of solutions • Factors that determine solution formation • Solubility rules and diffusion in liquids 	<ul style="list-style-type: none"> • Identifying types of solutions • Preparing dilute solutions • Determining solubility from solubility curves 	<ul style="list-style-type: none"> • Appreciate the differences in solution compositions.

Assessment

- Investigate and explain the factors that affect solubility of substances.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

A solution is a special type of homogeneous mixture composed of two or more substances. A solution is usually made up of a solute and a solvent.

Common types of solutions

1. Solid in liquid
2. Gas in liquid
3. Gas in gas
4. Liquid in liquid (miscible)
5. Solid in solid

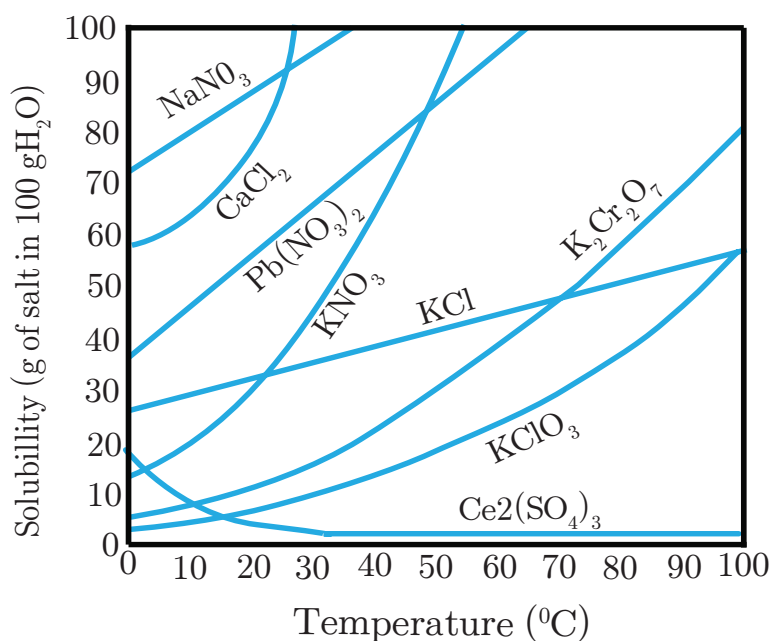
Solutions can either be concentrated or diluted depending on the amount of solute dissolved in a given volume of solvent. A concentrated solution is said to contain more solute particles. Concentration of solutions is measured in moles per litre (mol/L).

Solubility is the measure of the amount of solute that dissolves in a unit volume of solvent to form a saturated solution under specific conditions of temperature and pressure. Solubility is expressed usually as moles (n) of solute per 100 grams of solvent.

Solubility of substances is affected by three (3) factors:

1. Pressure
2. Temperature
3. Nature of solute and solvent.

The effects of temperature on solubility of substances are represented on solubility curves. The diagram below shows the solubility of salts measured in grams per 100 gram of water at different temperatures.



When expressing solubility of a substance, three (3) things must be mentioned:

1. The name of the solute
2. The name of the solvent
3. The specific temperature

i.e. The solubility of sodium chloride (NaCl) in water at 20°C is 36g/100g of H₂O.

Unit: Physical Chemistry

Topic: Gas Laws

Content Standard 11.2.3

Students will be able to investigate the physical structure of chemical compounds, the way they react with other matter and the bonds that hold their atoms together.

Benchmark 11.2.3.2

Explain the gas laws and use these to deduce the behaviour of gases.

Key question(s):

1. What are the different types of solutions?
2. What factors affect solubilities of substances?

Vocabulary:

Real gases, Ideal gases

Learning Objective(s)

By the end of the topic, students can:

- Explain the behavior of gases with respect to pressure, volume and temperature.
- Apply the gas laws to make quantitative calculations and conclusions.

Materials

Balloon, Syringe, cotton, gas samples (HCl and NH₃)

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Types of solutions • Factors that determine solution formation • Solubility rules and diffusion in liquids • pressure of gases • Concentrated and dilute solutions • Gas laws • Solubility of gases • Diffusion of gases • Pressure of gases 	<ul style="list-style-type: none"> • Identifying types of solutions • Preparing dilute solutions • Determining solubility from solubility curves • Applying the gas laws in a variety of situations • Determining the rates and order of chemical reactions • Handling laboratory equipment. 	<ul style="list-style-type: none"> • Appreciate the differences in solution compositions.

Assessment

- Investigate the behavior of gases and calculate their varying quantities using gas laws.
- Investigate and differentiate real and ideal gases.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Gases

A gas is a state of matter with no definite shape or volume. Gases have their own unique behavior depending on a variety of variables, such as temperature, pressure and volume. While each gas is different, all gases act in a similar manner.

Kinetic Theory of Gases

The kinetic theory of gases is a model which explains the properties of an ideal gas. It states that:

1. The volume of the gas particle is negligible compared to the total volume of gas.
2. The particles are in constant random motion. Collision between particles and the borders of the containers cause the pressure of the gas.
3. The average kinetic energy of the gas particles is directly proportional to the absolute temperature in Kelvin units (°K).
4. Industrial gas particles do not exert pressure on one another.

Gas Quantities

1. **Pressure** means force exerted per unit area. Pressure of a gas is the force it exerts on a surface within its volume. In gas law calculations, pressure is measured in Pascal's (Pa), kilo Pascal's (kPa) mmHg (torrs) and atmospheres (atm).
2. **Volume** is the amount of space occupied by the gas particles. It can be measured in millilitres (mL) or cubic centimetres (cm³).
3. **Temperature** measures the average kinetic energy of particles with respect to heat gained. In gas law calculations, all temperature reading must be in Kelvin units.

Conversion: Degrees to Kelvin

$$^{\circ}\text{K} = ^{\circ}\text{C} + 273$$

Example: Convert 30°C to °K

$$^{\circ}\text{K} = 30 + 273 = 303 \text{ }^{\circ}\text{K}$$

Standard Conditions

1. Standard temperature and pressure (STP)

$$0^{\circ}\text{C} = 273^{\circ}\text{K} = 1 \text{ atm} = 760 \text{ mmHg} = 101\,325 \text{ Pa}$$

2. Room temperature and pressure (RTP)

$$25^{\circ}\text{C} = 298^{\circ}\text{K} = 1 \text{ atm} = 760 \text{ mmHg} = 101\,325 \text{ Pa}$$

3. According to Avogadro, equal volumes of all gases at the same temperature and pressure contain the same number of particles (6.02×10^{23}).

$$\text{a. } \text{mole } (n) = \frac{\text{volume at STP}}{22.4\text{ l/mol}}$$

$$\text{b. } \text{mole } (n) = \frac{\text{volume at RTP}}{24\text{ l/mol}}$$

Gas Laws

1. **Boyles Law** states that for a fixed mass of gas at constant temperature, pressure is inversely proportional to volume.

$$P_1 V_1 = P_2 V_2$$

2. **Charles's Law** states that for a fixed mass of gas at constant pressure, volume is directly proportional to temperature.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

3. **Gay Lussac's Law** states that for a fixed mass of gas at constant volume, pressure is directly proportional to temperature.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

4. **Combine gas Law:** all gas laws combined gives:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Ideal gas law: considers not only pressure, volume and temperature but also moles (n) of gases.

$$PV = nRT$$

Where R = gas constant, ($R = 0.0821 \text{ Latm/molK}$)

Unit: Physical Chemistry

Topic: Gases and Solubility

Content Standard 11.2.3

Students will be able to investigate the physical structure of chemical compounds, the way they react with other matter and the bonds that hold their atoms together.

Benchmark 11.2.3.2

Explain the gas laws and use these to deduce the behaviour of gases.

Key question(s):

What laws govern the movement and behaviour of gases?

Vocabulary:

Partial pressure, Diffusion, Effusion, Atmospheric pressure, Effervescence

Learning Objective(s)

By the end of the topic, students can:

- Explain the behavior of gases with respect to pressure, volume and temperature.
- Apply the gas laws to make quantitative calculations and conclusions.

Materials

Balloon, Syringe, thermometer

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Movement of gases • Solubility of gases • Pressure of gases 	<ul style="list-style-type: none"> • gas laws in a variety of situations • Determining the rates and order of chemical reactions • Handling laboratory equipment 	<ul style="list-style-type: none"> • Appreciate the differences in solution compositions • Recognise the importance of behaviour and movement of gases.

Assessment

- Investigate and calculate the rate of diffusion of gases.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Dalton's Law

The law of partial pressure states that the total pressure exerted by a mixture of gases is equal to the sum of the partial pressure of the gases in the mixture.

$$P_{Total} = P_1 + P_2 + P_3 + etc...$$

Solubility of gases is directly affected by conditions like pressure and temperature.

Solubility of gases is directly proportional to pressure. This means that gases are more soluble at high pressure. For instance, carbonated drinks produce a fizzy sound and give off bubbles of gases because opening the drink container creates a low pressure and the dissolved gases (CO_2) evaporates.

Temperature is inversely proportional to the solubility of gases. Gases become less soluble at high temperatures.

Henry's Law

Henry's law states that for a fixed mass of gas at constant temperature, the solubility is directly proportional to pressure.

*Concentration of a gas = Constant \times Partial Pressure
(Solubility mol/L)*

$C = k_h \times P$ Where k_h is referred to as Henry's Law of constant.

Movement of gases

Diffusion describes the movement of particles to occupy available space, or the movement of particles from regions of high concentration to regions of low concentration.

Effusion describes the escape of air particles from a container through small holes or pores into vacuum or region of lower air pressure.

Graham's Law of Diffusion

Graham's law of diffusion states that the rate of diffusion of a gas is inversely proportional to the square root of its molar mass.

$$\frac{r_{G_A}}{r_{G_B}} = \sqrt{\frac{Mr_{G_B}}{Mr_{G_A}}}$$

Calculating Rate of Diffusion

Example 1

If you pop a balloon filled with Helium and oxygen at the same time, which gas will reach the end of the room first?

$$\frac{r_{He}}{r_{O_2}} = \sqrt{\frac{Mr_{O_2}}{Mr_{He}}} \rightarrow r_{He} = r_{O_2} \times \sqrt{\frac{32}{4}} = 2.83$$

The rate of diffusion of He is 2.83 times faster than the rate of diffusion of O_2 .

Example 2

If it takes 10 seconds for a sample of ammonia gas to diffuse, how long will it take for a sample of carbon dioxide gas to diffuse under the same conditions?

$$\frac{r_{NH_3}}{r_{CO_2}} = \sqrt{\frac{Mr_{CO_2}}{Mr_{NH_3}}} = \frac{T_{CO_2}}{T_{NH_3}} \rightarrow \sqrt{\frac{44}{17}} = \frac{T_{CO_2}}{10} \quad \therefore T_{CO_2} = 16.09 \text{ seconds}$$

Note: Rate of diffusion is directly proportional to molecular masses of gases.

Example 2

If it takes 10 seconds for a sample of ammonia gas to diffuse, how long will it take for a sample of carbon dioxide gas to diffuse under the same condition?

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Note: Rate of diffusion is directly proportional to molecular mass of gases.

Unit: Physical Chemistry**Topic: Energy and Chemical Reactions****Content Standard 11.2.3**

Students will be able to investigate the physical structure of chemical compounds, the way they react with other matter and the bonds that hold their atoms together.

Benchmark 11.2.3.3

Explain the role and applications of energy in chemical reactions.

Key question(s):

1. What laws govern energy production and used in chemical reactions?

Vocabulary:

Atmospheric pressure, Effervescence

Learning Objective(s)

By the end of the topic, students can:

- Explain the behavior of gases with respect to pressure, volume and temperature.
- Apply the gas laws to make quantitative calculations and conclusions.

Materials

Balloon, Syringe

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Exothermic reactions are reactions that give off energy • Exothermic reactions are reactions that absorb energy. 	<p>Applying the energy laws in a variety of situations</p>	<p>Recognise the importance of correct data collection methods in performing rate experiments</p>

Assessment

- Investigate and Calculate energy required in creating and breaking bonds to determine the heat of reaction.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

During chemical reactions, some reactions take in heat energy while others give off heat energy to the surrounding. Reactions that take in heat energy are known as **endothermic** reactions and reactions that give off heat energy are known as **exothermic reactions**.

The total energy stored in a substance in a form of either kinetic or potential energy is known as its **enthalpy**. It is also referred to as the heat content of the substance and is denoted by H .

Enthalpy change is the energy change during a reaction and is denoted by ΔH which is equal to the difference between the enthalpy of products and enthalpy of reactants. It is measured in kilojoules (kJ).

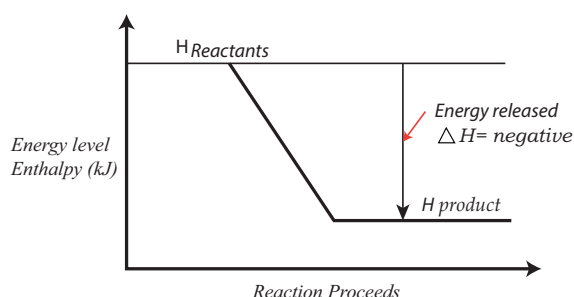
$$\begin{aligned} \text{Enthalpy change} &= \text{Enthalpy of products} - \text{enthalpy of reactants} \\ \Delta H &= H_p - H_R \end{aligned}$$

For endothermic reactions, enthalpy change is positive while in exothermic reactions, enthalpy change is negative.

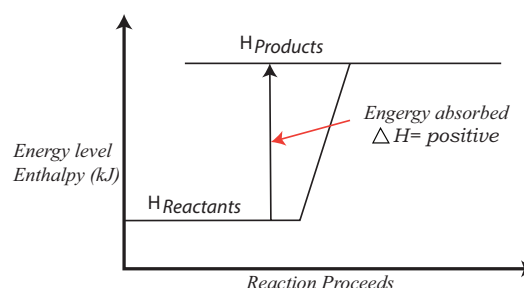
Energy Diagrams

Energy change in a reaction can be represented with energy diagrams.

1. Exothermic Reaction



2. Endothermic Reaction



During chemical reactions, energy is required to break bonds of reactants to form bonds in products. Thus, bond energy values are used to calculate the energy required for bond breaking and energy required for bond making to determine the heat of reaction (enthalpy change).

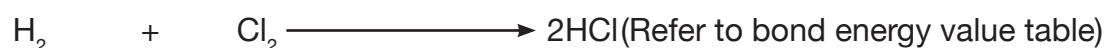
Calculating Heat of Reaction

In calculating heat of reaction:

- Bond breaking is an endothermic process
- Bond making is an exothermic process

A reaction is exothermic if ΔH bond breaking < ΔH bond making

Example: Determine whether the following reaction is exothermic or endothermic



Content Background

Step 1: Calculate the energy required to break bonds of reactants.

a) H-H bond (+ 436 kJ) **b)** Cl-Cl bond (+ 242 kJ)

Total energy required to break bonds = $436 + 242 = + 678$ kJ

Step 2: Calculate the energy required to make bonds.

$$\begin{aligned} 2[\text{H} - \text{Cl}] &= 2 \times (431) \\ &= - 862 \text{ kJ} \end{aligned}$$

Step 3: Determine the enthalpy change.

$$\begin{aligned} \Delta H &= \text{Energy required for bond breaking} + \text{Energy required for bond making} \\ &= (+ 678) + (- 862) \\ &= - 184 \text{ kJ} \end{aligned}$$

∴ The overall reaction is exothermic

Unit: Physical Chemistry	Topic: Reaction Rates
Content Standard 11.2.3	Students will be able to investigate the physical structure of chemical compounds, the way they react with other matter and the bonds that hold their atoms together.
Benchmark 11.2.3.3	Explain the role and applications of energy in chemical reactions.

Key question(s):

1. What is the collision theory of substances?
2. What laws govern rates of chemical reactions?

Vocabulary:

Endothermic reaction, exothermic reaction, Bond energy, Heat of reaction, Enthalpy change, Isothermic reaction, Activation energy

Learning Objective(s)

By the end of the topic, students can:

- Explain the behavior of gases with respect to pressure, volume and temperature.
- Apply the gas laws to make quantitative calculations and conclusions.

Materials

Sodium hydroxide pellets, Ammonia chloride, beakers, thermometer.

Knowledge	Skills	Attitudes and Values
Rates of chemical reactions	Mathematical skills for calculations	Recognise the importance of correct data collection methods in performing rate experiments

Assessment

- Investigate and explain the types of reaction rates.
- Investigate and explain factors that determine the rates of reactions.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Different chemical reactions take different lengths of time to be completed, for example, bombs explode at an instant, and food takes time to cook and ripening of banana which may take days.

Rate of reaction can be analysed by reviewing the Kinetic Particle Theory and the Collision Theory.

Kinetic Particle theory states that all matter is made up of tiny particles that are in constant random motion.

Collision Theory states that the greater the number of reacting particles colliding, the faster the rate of reaction.

Factors Affecting Rate of Reaction

1. Surface area of a solid reactant
2. Concentration or pressure of a reactant
3. Nature of the reactant
4. Presence or absence of catalyst.

Determining Rates of Reaction

Speed of reactions can be determined by measuring:

1. The amount of reactant used up per unit time.

$$\text{Speed of reaction} = \frac{\text{amount of reactants used up}}{\text{Time taken}}$$

2. The volume of gas produced per unit time.

$$\text{Speed of reaction} = \frac{\text{Volume of gas produced}}{\text{Time taken}}$$

3. Amount of product obtained per unit time.

$$\text{Speed of reaction} = \frac{\text{amount of product obtained}}{\text{Time taken}}$$

Rate Constant

The **rate constant**, k , is a proportionality constant that indicates the relationship between the molar concentration of reactants and the rate of chemical reaction.

The **rate law** is an expression showing the relationship of the reaction rate to the concentration each reactant.

The rate law and the rate constant for any chemical reaction must be determined experimentally. The value of rate constant is temperature dependent. A large value of rate constant means that the reaction is relatively fast and a small value indicate slow reaction.

For General Reaction



Thus, Rate constant
(at a specific temperature) $k = \frac{\text{Rate (mol/dms)}}{[A]^x [B]^y}$

Unit: Physical Chemistry

Topic: Equilibrium

Content Standard 11.2.3

Students will be able to investigate the physical structure of chemical compounds, the way they react with other matter and the bonds that hold their atoms together.

Benchmark 11.2.3.4

Explain and apply the equilibrium principle in chemical and physical changes

Key question(s):

1. What is the collision theory of substances?
2. What laws govern the physical and chemical equilibrium reactions?

Vocabulary:

Equilibrium, Equilibrium constant, Le Chanteliers' Principle, Physical equilibrium, Chemical equilibrium

Learning Objective(s)

By the end of the topic, students can:

- Apply the basic concepts to determine equilibrium conditions.

Materials

Test tube with cap, test tube rack, spectrophotomotre , various chemical s.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Equilibrium and Le Chateliers principle 	<ul style="list-style-type: none"> • Apply accurate methods of data collection during experimentation. 	<ul style="list-style-type: none"> • Recognise the importance of safety in science laboratory

Assessment

- Investigate and find the equilibrium constant of chemical reactions.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

An equilibrium state describes the concentration of reactants and products in a reaction mixture in closed system.

In equilibrium, the concentrations of reactions and products have constants. However, if the amount of a reactant or product is changed, the concentration of the other changes spontaneously to maintain equilibrium.

There are two (2) types of equilibrium

1. Physical Equilibrium

Physical equilibrium is an equilibrium in which the physical state of the system does not change when dynamic equilibrium is reached.

Example: When a pure solid is heated, it melts at a fixed temperature (melting point). Heating continues but temperature does not change until the whole solid changes to liquid.

2. Chemical Equilibrium

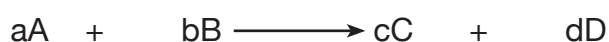
Chemical equilibrium is an equilibrium state in which the concentration of reactants and products are not changed with time and the rate of forward reaction equals the rate of backward reaction.

Equilibrium Constant

The equilibrium constant K_{eq} , is a variable that describes a chemical reaction's tendency to proceed to completion. Furthermore, it means that all reactants are converted to products.

Scientists use the equilibrium constant of an equation to understand how fast the equilibrium will be reached and whether the equilibrium will favour reactants or products.

For General Reaction:



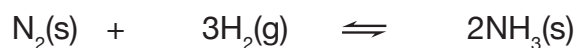
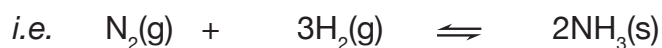
$$k_{eq} = \frac{[C]_{eq}^c}{[A]_{eq}^a [B]_{eq}^b}$$

Where: [A, B, C, D] are the concentration of reactants and products and a, b, c, d are the mole of each chemical.

Le Chatelier's Principle

Le Chatelier's Principle states that when a reaction at equilibrium is subjected to a change of temperature, pressure or concentration of one or more of the reacting substances, then the system adjusts to a new equilibrium stage as dictated by the change of variable.

Example: If pressure is increased for a system at equilibrium, the equilibrium shifts to the side with the least number of moles.



4 mols

2 mols

Equilibrium shifts to the right and more products form for this reaction.

Unit : Organic Chemistry

Topic: Carbon and its Compounds

Content Standard 11.2.4

Students will be able to examine and evaluate the structure, properties, composition, reactions and preparation of carbon-containing compounds.

Benchmark 11.2.4.1

Explain the properties and uses of carbon, its allotropes and compounds.

Key question(s):

1. What is the collision theory of substances?
2. What laws govern the physical and chemical equilibrium reactions?

Vocabulary:

Equilibrium, Equilibrium constant, Le Chanteliers' Principle, Physical equilibrium, Chemical equilibrium

Learning Objective(s)

By the end of the topic, students can:

- Apply the basic concepts to determine equilibrium conditions.

Materials

Test tube with cap, test tube rack, spectrophotomtre , various chemical s.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Properties of carbon • Uses of carbon and its compounds • Hybridization of the carbon atom 	<ul style="list-style-type: none"> • Comparing and contrasting chemical properties of elements. • Communicating Chemistry knowledge. 	<ul style="list-style-type: none"> • Appreciate the properties of carbon that enable it to form different compounds.

Assessment

- Investigate and explain why carbon exists in different allotropic forms.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

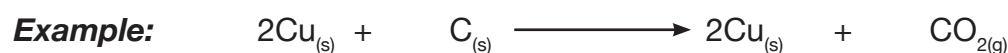
Carbon is a chemical element with the symbol C and atomic number 6. It is non-metallic and tetravalent, making four electrons available to form covalent chemical bonds. It is found in group IV of the periodic table.

Physical Properties of Carbon

Carbon is a soft, dull grey or black non-metal and is very brittle.

Chemical Properties of Carbon

Carbon does not dissolve in or react with water, acids or most other materials. It does however; react with oxygen to produce carbon dioxide, CO₂ and carbon monoxide, CO. It is also used as a reducing agent in the reduction of metal oxides.



Oxides of Zn, Fe, Pb, and Cu can be reduced by carbon. Carbon is also able to form long chains in forming hydrocarbons.

Allotropes of Carbon

Allotropes are different forms of the same element. For the element carbon, there are several. The two common ones are diamond and graphite. Although they are made of the same element, they have very different physical and chemical properties.

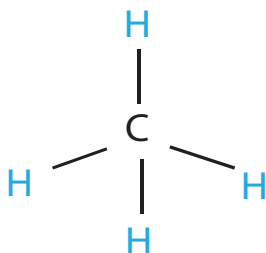
Hybridisation of Carbon

Hybridisation in chemistry is the concept of mixing atomic orbitals into new hybrid orbital. Carbon exists in 3 hybrid orbitals.

1. sp^3 hybridisation

When carbon atom is bonded to form other atoms with no lone pair of electrons, the hybridization is sp^3 and the arrangement is tetrahedral.

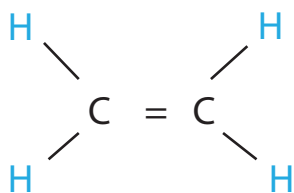
Example: methane



2. Carbon – sp^2 hybridisation

A carbon atom is bonded to three other atoms (one double bond and two single bonds) it is sp^2 hybridised. The arrangement is a flat trigonal.

Example: Ethene



3. Carbon sp Hybridisation

Carbon sp hybridisation occurs when carbon is bonded to two other atoms (one single and triple bond or two double bonds).

Example:



Unit: Organic Chemistry	Topic: Hydrocarbons
Content Standard 11.2.4	Students will be able to examine and evaluate the structure, properties, composition, reactions and preparation of carbon-containing compounds.
Benchmark 11.2.4.2	Determine the chemical names and formulae of carbon compounds using established rules and naming conventions.

Key question(s):
<ol style="list-style-type: none"> 1. What are the features of aliphatic compounds? 2. How can we write chemical formulae for aliphatic compounds? 3. How do we represent the structures of aliphatic compounds?

Vocabulary:
Hydrocarbons, Saturated hydrocarbons, unsaturated hydrocarbons, Aliphatic compounds, Aromatic compounds, Homologous series functional group.

Learning Objective(s)
<p>By the end of the topic, students can:</p> <ul style="list-style-type: none"> • Describe the main features of aliphatic compounds. • Distinguish between saturated and unsaturated hydrocarbons. • Write chemical formulae for aliphatic compounds. • Draw structural formulae for aliphatic compounds. • Apply rules for naming hydrocarbons.

Materials
Samples of organic substances.

Knowledge	Skills	Attitudes and Values
<ul style="list-style-type: none"> • Classification of hydrocarbons • Chemical formulae of hydrocarbons • Structural formulae • Functional groups • Naming rules for hydrocarbons 	<ul style="list-style-type: none"> • Applying definitions, classification schemes and naming rules • Drawing and interpreting structural formulae • Comparing and contrasting chemical properties of compounds • Communicating Chemistry knowledge 	<ul style="list-style-type: none"> • Appreciate the use of classification schemes and rules in chemistry

Assessment

- Apply the IUPAC rules to draw and name structures of organic compounds.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

All organic compounds contain the element carbon. Most organic compounds contain carbon and hydrogen only and are called Hydrocarbons. Organic compounds may also contain other elements such as oxygen, nitrogen and halogens.

Not all Carbon containing compounds are organic. For instance, carbon dioxide, carbon monoxide and carbonates are not classified as organic.

There are a lot of organic compounds and so scientists have classified them into groups with similar chemical properties or what is known as **homologous series**. Organic compounds in the same homologous series contain the same **functional group**. A functional group is the reactive part of an organic molecule.

Groups of organic compounds

1. Alkanes, alkenes, alkynes, (hydrocarbons)
2. Alcohol
3. Carboxylic acid
4. Aldehydes
5. Ketones
6. Esters
7. Amines

Names of organic compounds have two parts

1. Prefix – gives the number of carbon atoms

Example:	meth – 1	hex – 6
	eth – 2	hept – 7
	prop – 3	oct – 8
	but – 4	non – 9
	pent – 5	dec – 10

2. Suffix – identifies the family it belongs to

Example: methanol – alcohol
 methane – alkane

They have their own general formulae and naming systems follows the IUPAC rules (International Union of Pure and Applied Chemistry).

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 planning 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

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: Quantities and Measurement

Lesson Topic: Standard and Derived Units

Grade: 11

Length of Lesson: 40 minutes

National Content Standard: 12.1.1 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.

Grade Level Benchmark: 12.1.1.1. Identify appropriate quantities, their units and measurement methods using the metric system.

Essential Knowledge, Skills, Values, and Attitudes

Knowledge: Fundamental and derived units.

Skills: Evaluating - Reasoning

Values: Precise and accurate in interpreting information or data.

Attitudes: Responsible, truthful and correctness.

STEAM Knowledge and Skill

Knowledge: Reasons for standard and derived units.

Skill: Evaluating - Reasoning

Performance Indicator: Identify the essential processes in deriving units.

STEAM Performance Indicator: As above

Materials: Copies of conversion scales

- **Lesson Objective:** Students will be able to differentiate between Standard units and Derived Units

Essential Questions:

What are standard and derived SI units?'

What STEAM principles and practices can be used to enhance the ability to make conversions and derivations between units?.....

Lesson Procedure

Teacher Activities	Student Activities
Introduction	
<ul style="list-style-type: none"> Explain what students will learn and how it will be useful. Connect what they will learn to prior learning or experience. 	<ul style="list-style-type: none"> Listen to the teacher.
Body	
Modeling	
<ul style="list-style-type: none"> Identify and discuss a Standard and Derived units. 	<ul style="list-style-type: none"> Listen and respond when prompted by the teacher.
Guided Practice	
<ul style="list-style-type: none"> Give students a copy of the conversion scale. Ask students to read the conversion scale and identify one process involved in deriving units from standard units. Ask students to stop and give a process for deriving units. Ascertain if students understand what they are supposed to do. 	<ul style="list-style-type: none"> Read the conversion scale and identify one process involved in deriving units from standard units. Give one process given in the conversion scale in deriving units from standard units. Let teacher know if they understand what to do.
Independent Practice	
<ul style="list-style-type: none"> Ask students to read the conversion scale and identify one process involved in deriving units from standard units. Ask students to suggest and defend one process to derive units from standard units. 	<ul style="list-style-type: none"> Read the conversion scale and identify one process involved in deriving units from standard units. Suggest and defend one other conversion process to derive units from standard units.
Conclusion	
<ul style="list-style-type: none"> Emphasise the reasons given in the conversion scale to derive units from standard units. Ask students to provide a process given in the process for deriving units. 	<ul style="list-style-type: none"> Listen to the teacher. Give reasons to make conversions and their importance, orally

Performance Assessment and Standards

National Content Standard 12.1.1: 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.

Lesson Topic	Topic	Benchmark	Performance Assessment	
Standard and Derived Units	Quantities and Measurement	12.1.1.1. Identify appropriate quantities, their units and measurement methods using the metric system.	Student read the conversion scale and identify processes derive units from standard units.	
	PROFICIENCY RUBRIC			
	Advanced	Proficient	Partially Proficient	Novice
Identify all the processes given in derivation of units from standard units and justified at least one process	Identify all the processes given in the derivation of units from standard units.	Identify more than half of the processes given in deriving units from standard units.	Identify less than half of the processes given in the derivation of units from standard units	

STEAM Activity

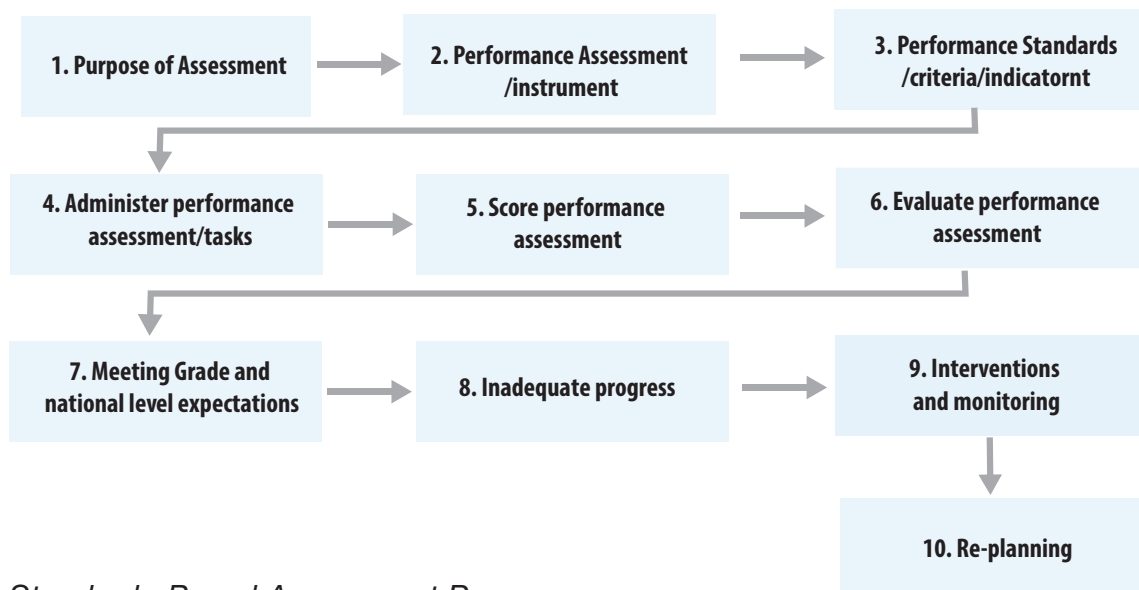
Students create a model of a measuring device that is essential in measuring and can be used in the derivation processes of units.

Assessment, Monitoring and Reporting

What is Standards-Based Assessment (SBA)?

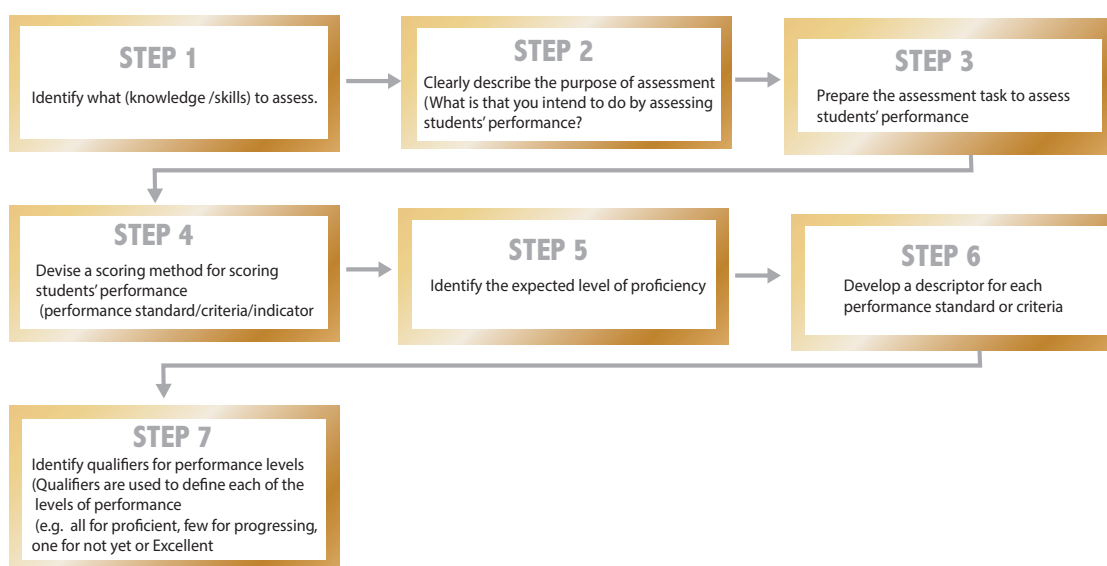
Assessment and reporting is an integral part of the delivery of any curriculum used in the schools. In Standard Based Curriculum (SBC) assessment encourages the use of benchmarks and commended types of assessment that promote standards for a range of purposes.

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 conducted 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.

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 2: Physical Science

Content Standard: 11.2.1 Students will be able to examine and explain the structure, properties and changes of motion with motion equation.

Topic: Object in Motion

Benchmark: 11.2.1.1 Derive and use equations of motion.

Lesson Title What is Kinematics?

Lesson Objective: By the end of the lesson, students should be able to describe kinematics.

Materials: Motion diagrams

What is to be assessed? (KSAVs)

Knowledge	Skills	Values and Attitudes
<ul style="list-style-type: none"> Solving problems using motion graphs 	<ul style="list-style-type: none"> Drawing up motion graphs and solve related problems 	<ul style="list-style-type: none"> Display confidence in drawing up motion graphs Appreciate the usefulness of objects in motion

Scientific Thinking: Think about how information from a real problem can be displayed onto a motion graph.

Purpose of the assessment

To measure students' proficiency on the achievement of the benchmark and learning objectives.

Expected level of proficiency

Design Motion graphs and display information in order to find solutions to given problems.

Assessment Strategy

This assessment can be conducted in one lesson as an assessed lesson exercise.

Performance Task

Draw a Motion graphs to represent given information to solve problems.

Assessment Tool

An exercise will be used to measure their level of proficiency

Assessment Scoring

Rubrics must be developed to articulate the real proficiency of the child. This is an analytical rubric 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 9 - 5	Progressing 3 - 4	Not Yet 2	___/10 Marks
Draw a Motion graphs to represent given information to solve related problems. 10 marks	Correct sketch of the Motion graphs and represented all information correctly and answered all the related questions with clear calculation steps	Correct sketch of the Motion graphs and represented all information correctly and answered all the related questions.	Satisfactory sketch of the Motion graphs and represented most information correctly and answered some of the related questions.	Poor sketch of the Motion graphs and represented few information and answered only one of the related questions.	

Recommended Resources:

- 'Grade 11 Physics Save Book'
- Worksheet
- Essential of Physics

Sample 2: Summative Assessment

Strand 2: Physical Science

Content Standard 11.2.1: Students will be able to examine and explain the structure, properties and changes of motion with motion equation.

Topics 1- 5: (Refer to the topics in kinematics unit)

Unit: Kinematics

Benchmark: 11.2.1.1 to 11.2.1.3 (Refer to the benchmarks in kinematics unit)

Lesson topics: (Refer to the lesson topics in kinematics unit)

Instructional Objective (s): (Refer to kinematics unit)

Knowledge	Skills	Values and Attitudes
<ul style="list-style-type: none"> Motion, equations of motion, trigonometry and algebraic laws. 	<ul style="list-style-type: none"> Drawing up Motion graphs and apply algebraic laws to solve related problems 	<ul style="list-style-type: none"> Appreciate the usefulness of Motion and problems display confidences in solving motion related problems.

Scientific Thinking: Think about how to solve motion related questions.

What is to be assessed? - (KSAVs)

The unit, Unit: “Kinematics” of Strand 2

Purpose of the assessment

To measure students’ proficiency on the achievement of the benchmarks and learning objectives in this unit. (This assessment is to be conducted after teaching the unit)

Expected level of proficiency

All students are expected to;

- Describe the characteristics of motion by applying the equations of motion and graphs.
- Explain characteristics of motion by using graphs

Assessment Strategy

This assessment can be conducted in one lesson as a unit test, or as an assignment.

Performance Task

Students will do an assignment out of 20 marks. You can use other assessment tools (assignment, projects, etc.) assess students proficiency on these benchmarks.

Task: Students will be given two week to complete this assignment. They are to;

1. Investigate who is the fastest runner in class.
2. Draw a motion graph to determine the speed of students.

Assessment Tool

An assignment will be used to measure students' 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 an assignment.

Performance standards/ Criteria	A	B	C	D	Score
	Advance 20	Proficient 13-19	Progressing 6-12	Not Yet 2-5	___/20 Marks
(10 marks) Criteria/ Constraints	Assignment was completed with all constraints and criteria met or exceeded. Reflects attention to detail and quality.	Assignment was completed with some of the constraints and criteria met. Reflects some attention to detail, but quality is minimal.	Assignment was completed with a few of the constraints and criteria met. Reflects minimal effort and lacks detail or quality.	Assignment was not completed and does not reflect the adherence to the constraints or criteria.	
(10 marks) Presentation of Motion Graph	Correct sketch of the Motion Graph and represented all information correctly and answered all the related questions with clear calculation steps	Correct sketch of the Motion Graph and represented all information correctly and answered all the related questions.	Satisfactory sketch of the Motion Graph and represented most information correctly and answered some of the related questions.	Shows poor knowledge of the person or persons involved in these major events	

Analysis. (3 marks)	Student carefully analyzed the information collected and drew appropriate and inventive conclusions supported by the evidence.	Student shows good effort in analyzing the evidence collected.	Student conclusions could have been supported by stronger evidence. Level of analysis could have been deeper	Student conclusions simply involved restating information. Conclusions were not supported by evidence.	
Time Management	Assignment completed and turned in on time. Student worked diligently when assignment time was available. Student was on task most of the time.	Assignment was completed, but had notable errors. Student utilized assignment time somewhat efficiently, but spent time socializing. Student was on task 70% - 80% of the time.	Assignment was not turned in on time and/or complete. The student was on task less than 60% of the time.	Assignment was not turned in on time and was not completed. Student wasted Assignment time and at times was disruptive to others.	

Recommended Resources:

- Essential of Physics
- Grade 11 Physics Save Book

Sample 3: Authentic Assessment

Strand 2: Physical Science

Content Standard: 11.2.2 Students will be able to Investigate and derive Newton's Laws of motion and apply it to solve real life problems.

Unit : Force and Motion

Benchmark: 11.2.2.1 to 11.2.2.5 (Refer to the benchmarks in unit: force and motion, strand 2)

Topics: (Refer to the topics in the unit force and motion)

Instructional Objective: (Refer to the topics in unit: force and motion, strand 2)

What is to be assessed? - (KSAVs)

The essential knowledge, skills, attitudes and values in the unit "Force and Motion"

Purpose of the assessment

To measure students proficiency on the achievement of the benchmarks and learning objectives in this unit. This assessment is to be conducted after teaching this unit.

Expected level of proficiency

All students are expected to:

- Use vectors to explain force and motion
- Apply the laws of motion to determine the effects of forces on the linear motion of objects
- Explain the characteristics of motion by using graphs

Assessment Strategy

This assessment can be conducted as a project, practical test or assignment relating to a real life situation.

Performance Task

Students will do a Real World Application Project (Sinusoidal Modeling) out of 30 marks. You can use other assessment tools (assignment, projects, etc.) to assess student's proficiency on these benchmarks.

Task: Students will be given three weeks to complete this project. They are to:

- Investigate any real-world phenomenon that can be modelled by a sinusoid.
- Research and collect data, develop a predictive model, graph it, and present it to the class using a visual presentation platform like, iMovie, Powerpoint, etc.
- Choose any topic, and the freedom to be as creative and outside-the-box with this project as they wish.

Note: Students should now understand that any variable that is cyclical, harmonic, oscillating, or periodic in nature can be modeled graphically by a sine or cosine wave. There are countless applications of sinusoid modeling in real life.

Some of these applications include:

- Changes in Temperature over time.
- Hours of daylight over time.
- Population growth/decay over time.
- Ocean wave heights (high and low tides) over time .
- Sound waves.
- Electrical currents.
- Ferris wheels and roller coasters.
- Tsunamis and tidal waves.
- Earthquakes.
- Wheels and Swings.

Task Details: Students are to;

- Collect no less than 12 real-world data points that can be modeled sinusoidally. The more data, the better! Providing 24 or more data points will earn maximum points on the rubric.
- A predictive model of the format $y = A\sin(Bx + C) + D$ or $y = A\cos(Bx + C) + D$ for the data must be developed using the techniques they learned in class. This model could be used to predict outcomes into the future.
- A neatly organized graph of the original data and a graph of their developed model must both be embedded in their presentation. To produce these graphs they may use their graphing calculators, the Desmos app, or they may draw the graphs themselves. Pictures or screenshots of their graphs may be used. The objective is to compare the two graphs side-by-side or on top of one another, so they could see how accurate and predictive their model is.
- A reflection must be submitted with your project (1-2 paragraphs). This reflection should be neatly and logically written/typed with no grammatical errors, and should summarize their experience in doing this project. What did they learn? What did they enjoy or dislike? What would they change? How well did they work with their partner? Etc.

Criteria	Model/Exemplar (4 points)	Proficient (3 points)	Developing (2 points)	Beginning (1 point)	
Data Collection	Data is authentic, appropriately labeled and clearly presented in an X-Y table. Contains 24 or more measurements.	Data is authentic, appropriately labeled and clearly presented in an X-Y table. Contains 13-23 measurements.	Data is authentic, appropriately labeled and clearly presented in an X-Y table. Contains 12 measurements.	Data is incorrectly labeled, not presented in an X-Y table, and contains less than 12 measurements.	
Mathematical Calculations/ Model Development	All calculations are very clear, organized, and neatly completed with no inaccuracies.	All calculations are clear, organized, and neatly completed with 1-2 inaccuracies.	Most calculations are clear, organized, and neatly completed with 3-4 inaccuracies.	Calculations are unclear and disorganized and 5 or more inaccuracies may be present.	
Graphs	All graphs are neatly produced, axes are appropriately scaled and labeled, data points are accurately plotted, colorful, and smooth curves are drawn.	All graphs are neatly produced, axes are appropriately scaled and labeled, data points are accurately plotted, colorful, and smooth curves are drawn.	All graphs are not neatly produced, axes are not appropriately scaled and labeled, data points are not accurately plotted, and smooth curves are not drawn.	All graphs are not neatly produced, axes are not appropriately scaled and labeled, data points are not accurately plotted, and smooth curves are not drawn	

Visual Presentation	The presentation is clear, colorful, creative and entertaining, shows a great deal of editing and audio/visual effects, keeps the audience fully engaged, fully utilizes available technology, and lasts 5-10 minutes.	The presentation is clear and colorful, shows some editing and audio/visual effects, keeps the audience mostly engaged, and fully utilizes technology, and lasts 3-5 minutes	The presentation is bland and basic, does not show editing or effects, keeps the audience moderately engaged, and does not fully utilize technology, and lasts 1-2 minutes	The presentation is erratic and poorly produced, lacks effort, does not show any editing or effects, the audience is not engaged, and does not utilize technology, and lasts under 1 minute.	
Effort and Collaboration	An exceeding amount of time and effort are present and the task responsibilities were shared equitably among group partners.	A substantial amount of effort is present and the task responsibilities were shared equitably among group partners.	An average amount of effort is present, and the task responsibilities were not shared equitably among group partners.	A poor amount of effort is present, and the task responsibilities were not shared equitably among group partners.	
Reflection	Writing is clear, concise, and well organized. Thoughts are expressed in a coherent and logical manner. Contains 2 or more paragraphs with very few grammatical errors present.	Writing is mostly clear, concise, and well organized. Thoughts are expressed in a coherent and logical manner. Contains 1-2 paragraphs with several grammatical errors present.	Writing is unclear and disorganized. Thoughts are not expressed in a logical manner. Contains 1-2 paragraphs with several grammatical errors present.	Writing is unclear and disorganized. Thoughts ramble and make little sense. Contains 1 paragraph with many grammatical errors present.	

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 12 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 12 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.

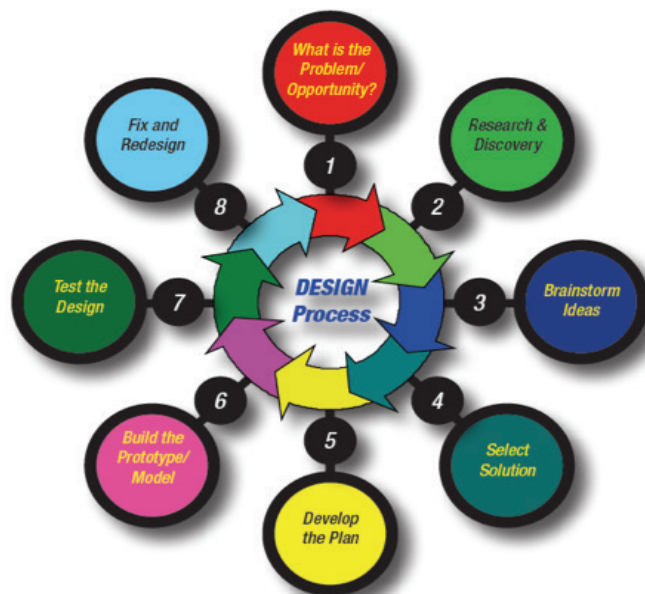
The grade 12 Science teachers will now do the following;

- (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 12 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

<p>Time Management</p>	<p>Project completed and turned in on time. Student worked diligently when project time was available. Student was on task most of the time.</p>	<p>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.</p>	<p>Project was not turned in on time and/or complete. The student was on task less than 60% of the time.</p>	<p>Project was not turned in on time and was not completed. Student wasted project time and at times was disruptive to others.</p>
<p>Resource Management</p>	<p>Always takes responsibility for use and care of all building components and resources. Always returns building components and materials to proper storage compartments.</p>	<p>Consistently takes responsibility for use and care of building components and resources. Somewhat consistent in returning building components to proper storage compartments.</p>	<p>Sometimes takes responsibility for use and care of building components and resources. Inconsistent in returning building components to proper storage compartments.</p>	<p>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.</p>
<p>Teamwork</p>	<p>Notable teamwork shown with a determination to participate/contribute to team success. Completed required individual tasks that contributed to the success of the team.</p>	<p>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.</p>	<p>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.</p>	<p>Was not a team player. Either took over project completely, or did not engage in team direction or plans.</p>
<p>Writing/ Reflection</p>	<p>Writing/reflection is very well organized and explained. Student includes all details in design process. Document has almost no grammatical errors.</p>	<p>Writing/reflection is somewhat organized and explained. Student includes most details in design process. Document has very few grammatical errors.</p>	<p>Writing/reflection is not organized and explained. Student includes only a few details in design process. Document has many grammatical errors.</p>	<p>Writing/reflection is incomplete or not turned in. Student includes no details in design process. Document has many grammatical errors.</p>
<p>Presentation</p>	<p>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.</p>	<p>Presentation was fairly organized and most information presented in a logical sequence. Answers to questions were vague or lacked clarity or accuracy.</p>	<p>Presentation was unorganized and lacked a logical sequence. Presentation reflected little attention to detail. Answers to questions were inaccurate and confusing.</p>	<p>Presentation was not acceptable and reflects a lack of organization or knowledge of the topic. Presentation shows little effort to meet expectations.</p>

Glossary

Words	Definition
Acid	A sour-tasting compound that releases hydrogen ions to form a solution with a pH less than 7, reacts with base to form a salt, and turns blue litmus paper red
Analytical Chemistry	The study and use of instruments and methods used to separate, identify and quantify matter.
Atom	The smallest portions into which an element can be divided and still retain its properties, made up of a dense, positively charged nucleus surrounded by a system of electrons.
Base	A compound that releases hydroxyl ions to form a solution with a pH greater than 7, reacts with acids to form salts, and turns red litmus paper blue
Carboxylic Acid	An organic acid that contains the carboxyl group.
Chemical Bond	A force resulting from the redistribution of energy contained by orbiting electrons, which tends to bind atoms together to form molecules.
Compound	A substance formed by the chemical combination of elements in fixed proportions
Electron	A stable negatively charged elementary particle with a small mass that is a fundamental constituent of matter and orbits the nucleus of an atom.
Electrochemistry	A branch of chemistry that studies chemical change associated with electrons and electricity.
Element	Any substance that cannot be broken down into a simpler one by a chemical reaction.
Empirical Formula	A chemical formula showing the relative proportion of elements in a compound instead of their structural arrangement or molecular weights, e.g. the formula H_2O .
Inorganic Chemistry	The branch of chemistry relating to inorganic compounds.
Ion	An atom or group of atoms that has acquired an electric charge by losing or gaining one or more electrons.
Matter	The material substance of the universe that has mass, occupies space, and is convertible to energy.
Molecular Formula	A chemical formula that specifies which atoms and how many of each atom there are in a molecule of a compound.
Molecule	The smallest physical unit of a substance that can exist independently, consisting of one or more atoms held together by chemical forces.
Organic Chemistry	The scientific study of carbon-based compounds, originally limited to compounds that are the natural products of living things, now including the study of synthetic carbon compounds such as plastics.
Physical Chemistry	The branch of chemistry that studies the physical and thermodynamic properties of substances in relation to their structures and chemical reactions.
Substance	A type of matter or material.

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Appendices

Appendix 1: Bloom's Taxonomy

LEVEL OF UNDERSTANDING	KEY VERBS
CREATING 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 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 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 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 Can the student comprehend ideas or concepts?	Classify, compare, exemplify, conclude, demonstrate, discuss, explain, identify, illustrate, interpret, paraphrase, predict, report, translate, describe, classify,
REMEMBERING 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 Think creatively Work creatively with others Implement innovations Critical thinking, problem solving and decision making Reason effectively and evaluate evidence Solve problems Articulate findings Learning to learn and meta-cognition Self-motivation Positive appreciation of learning Adaptability and flexibility
WAYS OF WORKING	Communication Competency in written and oral language Open minded and preparedness to listen Sensitivity to cultural differences Collaboration and teamwork Interact effectively with others Work effectively in diverse teams Prioritise, plan and manage projects
TOOLS FOR WORKING	Information literacy Access and evaluate information Use and manage information Apply technology effectively ICT literacy Open to new ideas, information, tools and ways of thinking Use ICT accurately, creatively, ethically and legally Be aware of cultural and social differences Apply technology appropriately and effectively
LIVING IN THE WORLD	Citizenship – global and local Awareness and understanding of rights and responsibilities as a global citizen Preparedness to participate in community activities Respect the values and privacy of others Personal and social responsibility Communicate constructively in different social situations Understand different viewpoints and perspectives Life and career Adapt to change Manage goals and time Be a self-directed learner 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	

Performance Assessment and Standards

National Content Standard :			
Lesson Topic	Topic	Benchmark	Performance Assessment
	PROFICIENCY RUBRIC		
	Advanced	Proficient	Partially Proficient

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:

Lesson Procedure

Teacher Activities	Student Activities
Introduction	
Body	
Modelling	
Guided Practice	
Independent Practice	
Conclusion	

Performance Assessment and Standards

National Content Standard :				
Lesson Topic	Topic	Benchmark	Performance Assessment	
	PROFICIENCY RUBRIC			
	Advanced	Proficient	Partially Proficient	Novice

STEAM Activity

Students create a model of a mine that is going to be closed soon shown in the plan and the natural environment that is worth rehabilitating using the values of common good, sustainability, and interdependence; and the attitudes of caring, responsible, and respect.

Appendix 5: Time Allocation

SBC Senior High School Time Allocation						
No.	Subject	Periods/Week	Sample Period and Time Break ups		Total min/week	
			Single Period	Block Period		
1	English	8	2 x 40 min	3 x 80 min	320	
2	General Mathematics	8	2 x 40 min	3 x 80 min	320	
3	Advanced Mathematics	10	5 x 80 min (2 periods/day)		400	
4	Citizenship and Christian Values Education	2	2 x 40 min		80	
5	Character and Social Development	2	2 x 40 min		80	
6	Physical Education	3	1 x 40 min	1 x 80 min	120	
7	Geology	6	4 x 40 min	1 x 80 min	240	
8	Physics	6	4 x 40 min	1 x 80 min	240	
9	Biology	6	4 x 40 min	1 x 80 min	240	
10	Chemistry	6	4 x 40 min	1 x 80 min	240	
11	Agriculture	6	3 x 40 min	1 x 120 min	240	
12	Social Science	Geography	6	4 x 40 min	1 x 80 min	240
		History	6	4 x 40 min	1 x 80 min	240
		Political Science	6	4 x 40 min	1 x 80 min	240
		Economics	6	4 x 40 min	1 x 80 min	240
		Environment	6	4 x 40 min	1 x 80 min	240
13	Arts	Music	6	4 x 40 min	1 x 80 min	240
		Theatre Arts	6	4 x 40 min	1 x 80 min	240
		Visual Arts	6	4 x 40 min	1 x 80 min	240
14	Business Studies	6	4 x 40 min	1 x 80 min	240	
15	Technology and Industrial Arts	Textile Technology	6	3 x 40 min	1 x 120 min	240
		Food Technology	6	3 x 40 min	1 x 120 min	240
		Construction Technology	6	3 x 40 min	1 x 120 min	240
		Communication Technology	6	3 x 40 min	1 x 120 min	240
		Computer Technology	6	3 x 40 min	1 x 120 min	240
16	Information Communication, Computer Technology	3		1 x 120 min	120	
17	Guidance				40	
18	Library Skills				40	
19	Religious Education				40	

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