SCI401A

SCIENCE

Grade 10 Science

Curriculum Guide

Prince Edward Island
CANADA

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Introduction

The pan-Canadian Common Framework of Science Learning Outcomes K to 12 (1997) assisted in standardizing science education across Canada. This framework was used to develop the Foundation for the Atlantic Canada Science Curriculum (1998). Sections of the Atlantic Canada Science Foundation Document have been incorporated into this revision and augmented with ideas and standards presented in newer Canadian provincial science curricula and recent literature concerning science education. This includes the National Research Council's Framework for K–12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas (2012), and the resulting Next Generation Science Standards: For States, By States (2013).

The revised science curriculum is designed to enable learners to work towards the achievement of six, cross-curricular essential graduation competencies (EGCs) as defined by the Council of Atlantic Ministers of Education and Training (CAMET) in The Atlantic Canada Framework for Essential Graduation Competencies (2015). To facilitate this shift to competency-based education, a number of significant changes have been incorporated in this guide: 1) specific curriculum outcomes (SCOs) have been reduced and targeted toward EGCs; 2) greater emphasis has been placed on processes and skills; and 3) achievement indicators (AIs) have been included to clarify the "depth and breadth" of SCOs.

Vision

The Prince Edward Island science curriculum is guided by the vision that all learners will have the opportunity to develop scientific literacy. Scientific literacy is the set of knowledge, skills, and attitudes that enables an individual to inquire, problem solve, critically evaluate and make well-informed decisions, and maintain a sense of wonder about the world around them.

Scientific Literacy

As we progress through the 21st century, humans have created a world that confronts us daily with issues of a scientific and technological nature: global warming, decreasing sources of clean water, cloning, multi-drug-resistant bacteria, evolving viruses, nanotechnology, genetically modified organisms (GMOs), waste disposal, new sources of energy, dependency on electronic devices, suburbanization, and new frontiers in space exploration. In order to play an active role in this world of change, individuals must have a degree of scientific literacy that enables them to sort through valid and invalid claims and understand the implications of new developments.

Scientifically literate people have a fundamental knowledge about the natural world around them and an understanding of the scientific processes that were used to obtain such knowledge. They are aware that knowing something scientifically requires evidence that passes through a rigorous process of review, evaluation, and support by a global community of experts, and that this process extends over time. They recognize our understanding of the natural world is not static but constantly evolving; what we "know" today may change as new concepts and technologies are developed. Whether or not they work in a science-related field, scientifically literate people are able to make informed personal, political, economic, and ethical decisions regarding science and technology matters by evaluating evidence, and are able to defend their decisions using rational reasoning.

Introduction

Aim

The Prince Edward Island science curriculum aims to facilitate the development of scientifically literate learners by providing opportunities to develop and apply an understanding of the nature of science to evaluate claims related to science; develop skills and strategies required to perform scientific inquiry and apply science to solve problems; work collaboratively to generate and explore ideas, and carry out investigations; reason scientifically; develop foundational understanding of scientific concepts that explain the natural and material world; communicate scientific information effectively; evaluate the personal, societal, environmental, and ethical implications of the applications of science and technology from a variety of perspectives.

Attitudes

Positive attitudes towards science will also be fostered in our learners. Attitudes are generalized aspects of behaviour that can be modelled by adults and encouraged by selective approval. Positive attitudes include, but are not limited to

- exhibiting a sense of wonder and curiosity about scientific and technological endeavours;
- engaging and persevering in science tasks and projects;
- demonstrating resilience;
- showing concern for safety during inquiry activities;
- exhibiting collaborative behaviours;
- valuing the role of science and technology in our understanding of the world;
- demonstrating an appreciation of the nature of science;
- demonstrating respect and sensitivity in maintaining a balance between the needs of humans and the environment; and
- being open-minded and projecting beyond the personal consequences of proposed actions.

Purpose of Curriculum Guide

The overall purpose of this curriculum guide is to advance science education through teaching and learning, and, at the same time, recognize and validate effective practices that already exist in many classrooms. More specifically, this curriculum guide

- provides detailed curriculum outcomes to which educators and others can refer to when making decisions concerning learning experiences, instructional techniques, and assessment strategies for the social studies program;
- informs both educators and members of the general public about the philosophy and scope of science education for the senior high school level in Prince Edward Island;
- promotes the effective learning and teaching of science for learners.

Essential Graduation Competencies (EGC's)

Curriculum is designed to articulate what learners are expected to know and be able to do by the time they graduate from high school. The PEI Department of Education and Lifelong Learning designs curriculum that is based on the Atlantic Canada Framework for Essential Graduation Competencies released by the Council of Atlantic Ministers of Education and Training (CAMET 2015).

Competencies articulate the interrelated sets of attitudes, skills, and knowledge—beyond foundational literacy and numeracy—that prepare learners to successfully participate in lifelong learning and life/work transitions. They are cross-curricular in nature and provide opportunities for interdisciplinary learning. Six competencies have been identified: citizenship, communication, personal-career development, creativity and innovation, critical thinking, and technological fluency (Figure 1). Achievement of the essential graduation competencies (EGCs) will be addressed through the assessment and evaluation of curriculum outcomes developed for individual courses and programs.

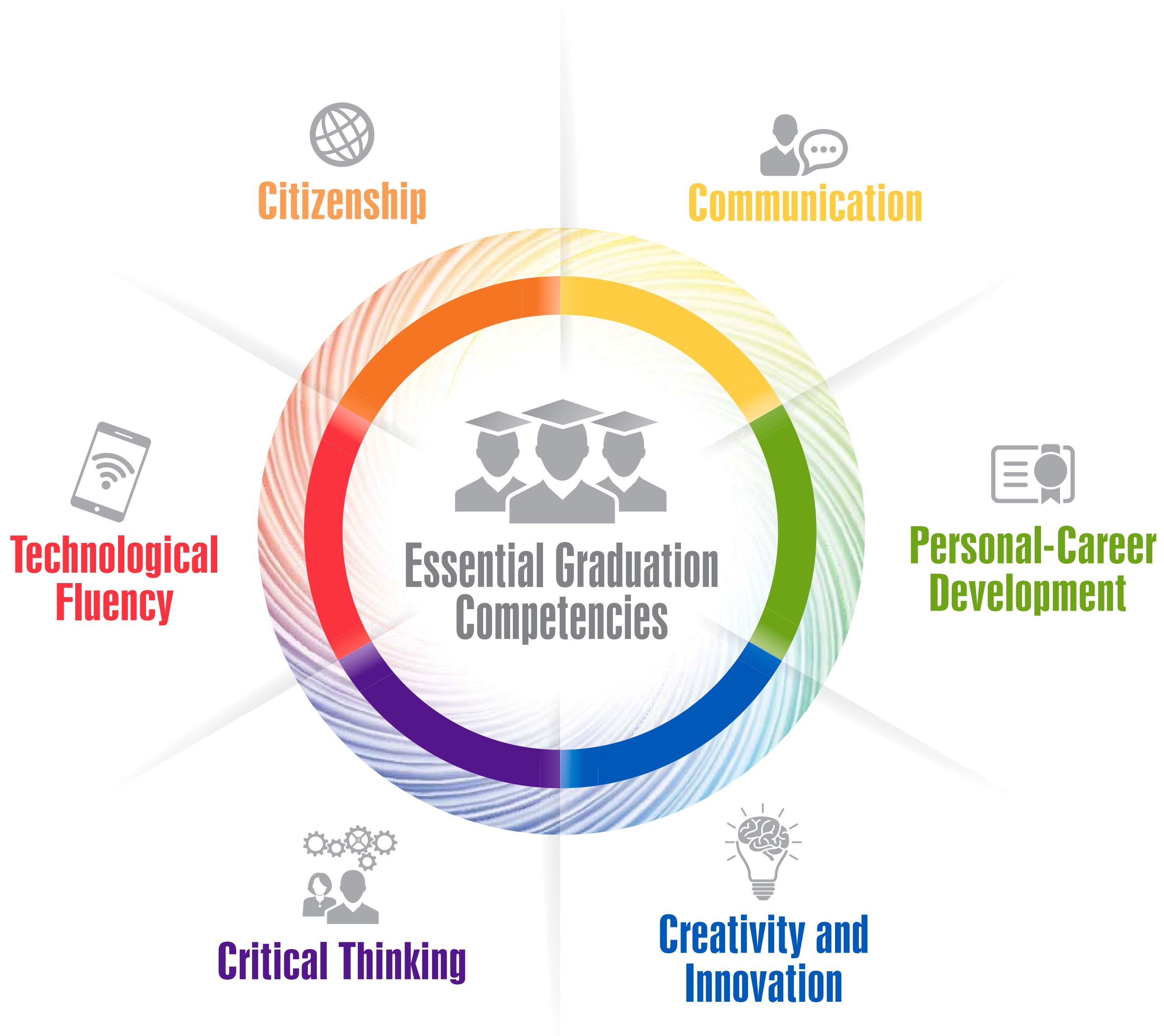

Figure 1. *Essential Graduation Competencies*

Essential Graduation Competencies—Definitions

Critical Thinking

Learners are expected to analyse and evaluate evidence, arguments, and ideas using various types of reasoning and systems thinking to inquire, make decisions, and solve problems. They reflect critically on thinking processes.

Learners are expected to

- use critical thinking skills to inquire, make decisions, and solve problems;
- recognize that critical thinking is purposeful;
- demonstrate curiosity, inquisitiveness, creativity, flexibility, persistence, open- and fair-mindedness, tolerance for ambiguity, and suspension of judgment;
- ask powerful questions which support inquiry, decision-making, and problem solving;
- acquire, interpret, and synthesize relevant and reliable information from a variety of sources;
- analyse and evaluate evidence, arguments, and ideas;
- use various types of evidence, reasoning, and strategies to draw conclusions, make decisions, and solve problems;
- reflect critically on thinking processes used and acknowledge assumptions;
- effectively communicate ideas, conclusions, decisions, and solutions; and
- value the ideas and contributions of others who hold diverse points of view.

Technological Fluency

Learners are expected to use and apply technology to collaborate, communicate, create, innovate, learn, and solve problems. They use technology in a legal, safe, and ethically responsible manner.

Learners are expected to

- recognize that technology encompasses a range of learning tools and contexts;
- use and interact with technology to create new knowledge;
- apply digital technology to gather, filter, organize, evaluate, use, adapt, create, and share information;
- select and use technology to impact and advance one another; and
- adopt, adapt, and apply technology efficiently, effectively, and productively.

Curriculum Design

Citizenship

Learners are expected to contribute to the quality and sustainability of their environment, communities, and society. They analyse cultural, economic, environmental, and social issues; make decisions and judgments; and solve problems and act as stewards in a local, national, and global context.

Learners are expected to

- recognize the principles and actions of citizens in just, pluralistic, and democratic societies;
- demonstrate the disposition and skills necessary for effective citizenship;
- consider possible consequences of decisions, judgment, and solutions to problems;
- participate in civic activities that support and promote social and cultural diversity and cohesion;
- promote and protect human rights and equity;
- appreciate the complexity and interconnectedness of factors in analysing issues; and
- demonstrate understanding of sustainable development.

Communication

Learners are expected to express themselves and interpret effectively through a variety of media. They participate in critical dialogue, listen, read, view, and create for information, enrichment, and enjoyment.

Learners are expected to

- listen and interact purposefully and respectfully in formal and informal contexts;
- engage in constructive and critical dialogue;
- understand, interpret, and respond to thoughts, ideas, and emotions presented through multiple media forms;
- express ideas, information, learnings, perceptions, and feelings through multiple media forms, considering purpose and audience;
- assess the effectiveness of communication and critically reflect on intended purpose, audience, and choice of media; and
- analyse the impact of information and communication technology.

Personal-Career Development

Learners are expected to become self-aware and self-directed individuals who set and pursue goals. They understand and appreciate how culture contributes to work and personal life roles. They make thoughtful decisions regarding health and wellness, and career pathways.

Learners are expected to

- connect learning to personal and career development;
- demonstrate behaviours that contribute to the well-being of self and others;
- build healthy personal and work relationships;
- establish skills and habits to pursue physical, spiritual, mental, and emotional well-being;
- develop strategies to manage career balance and wellness;
- create and implement a personal, education, career, and financial plan to support transitions and achievement of personal, education, and career goals; and
- demonstrate preparedness to learn and work individually, cooperatively, and collaboratively in diverse, evolving environments.

Creativity and Innovation

Learners are expected to demonstrate openness to new experiences; to engage in creative processes; to make unexpected connections; and to generate new and dynamic ideas, techniques, and products. They value aesthetic expression and appreciate the creative and innovative work of others.

Learners are expected to

- gather information through all senses to imagine, create, and innovate;
- develop and apply creative abilities to communicate ideas, perceptions, and feelings;
- take responsible risk, accept critical feedback, reflect, and learn from trial and error;
- think divergently, and embrace complexity and ambiguity;
- recognize that creative processes are vital to innovation;
- use creation techniques to generate innovations;
- collaborate to create and innovate;
- critically reflect on creative and innovative works and processes; and
- value the contribution of creativity and innovation.

Curriculum Design

Foundations of Scientific Literacy

PEI science curriculum is based upon four foundations deemed essential to scientific literacy. Three of these components–Procedural Knowledge, Content Knowledge, and Decisions and Perspectives–reflect 1) the processes and skills required in the development and application of scientific knowledge, 2) the resulting body of knowledge, and 3) the need for critical thinking about the application of science developments from a variety of perspectives and with consideration of ethics. Central to these three foundations is the Nature of Science, which addresses epistemic knowledge or the principles underlying science as a way of knowing. More detail relating to these concepts can be found in the section "Foundations of Scientific Literacy" p.22. The foundations of science literacy support and are integrated with the six essential graduation competencies.

Figure 2. *Nature of Science*

General Curriculum Outcomes

General curriculum outcomes statements articulate what learners are expected to know and be able to do upon completion of study in Science education.

Nature of Science (NoS)

Learners will comprehend science as a way of knowing about the natural world that uses valid, empirical evidence and logical reasoning. They will recognize that scientific knowledge is dynamic and probabilistic in its nature, evolving as new evidence and ideas are presented, and accepted by a community of scientists only after rigorous review.

Procedural Knowledge (PK)

Learners will understand and become proficient using skills, processes, and practices required for scientific inquiry and the application of science. This includes the skills necessary for reading comprehension, argumentation, communication, collaboration, computational thinking, mathematical analysis, and technological fluency.

Content Knowledge (CK)

Learners will integrate knowledge and understanding of concepts related to life sciences, physical sciences, Earth and space sciences, and their real-world applications. They will think critically about these understandings to extend their knowledge of themselves and the world around them.

Decisions and Perspectives (DP)

Learners will evaluate personal, societal, environmental, ethical, and sustainability issues relating to the applications of science and technology from multiple perspectives. This includes exploring science-related career pathways.

Curriculum Design

Specific Curriculum Outcomes

Specific curriculum outcomes (SCOs) identify what learners are expected to know and be able to do for a particular course. They provide a focus for instruction in terms of measurable or observable learner performance and are the basis for the assessment of learner achievement across the province. PEI specific curriculum outcomes are developed with consideration of Bloom's Taxonomy of Learning and the Essential Graduation Competencies.

SCOs will begin with the phrase—Learners are expected to… .

Achievement Indicators (AIs)

Each specific curriculum outcome is described by a set of achievement indicators that aid in defining and demonstrating the depth and breadth of the corresponding SCO.

Taken together as a set, AIs support the SCO in defining specific levels of knowledge acquired, skills applied, or attitudes demonstrated by a learner for that particular outcome. Achievement indicators provide clarity for understanding and ensure instructional design is aligned to the SCO.

When planning for instruction, teachers must be mindful of the complete set of achievement indicators in order to fully understand the breadth and depth of the outcome. Teachers may alter, or add to, the existing indicators to be responsive to the interests, lives, and prior knowledge of learners. It is important to note that changes to the given indicators must be reflective of, and consistent with, the intended breadth and depth of the outcome.

The set of achievement indicators for a given outcome begins with the phrase—Learners who have achieved this outcome should be able to… .

Elaborations

An elaboration provides a fuller description of the SCO and the instructional intent behind it. It provides a narrative for the SCO, gives background information where possible, and offers a broader context to help teachers gain a deeper understanding of the scope of the SCO. This may also include suggestions and/or reference supporting resources that may be helpful for instruction and assessment of the SCO.

Curriculum Design

Bloom's Taxonomy

Bloom's Taxonomy was published in 1956 as a framework for the purpose of classifying expectations for student learning as indicated by educational outcomes. David Krathwohl's 2002 revision of this taxonomy expands on the original work by defining the relationship between the cognitive process dimension—how we expect learners to come to know and think about the outcome—and the knowledge dimension—the category of knowledge expressed by the outcome.

A full understanding of the relationship between the cognitive process and knowledge dimensions of Bloom's Taxonomy will serve learners, teachers, and administrators by

- providing a framework for developing the specific curriculum outcomes (SCOs) for a particular course;
- identifying the type of knowledge and cognitive target of the outcome;
- providing a means for the alignment of specific curriculum outcomes with instructional activities and assessments; and
- providing a common language about the curriculum outcomes within all subjects to facilitate communication.

Cognitive Process Dimension

The cognitive process dimension classifies six types of cognition that learners may be expected to demonstrate or use as they work towards proficiency of any given specific curriculum outcome. The verb(s) that begins a specific curriculum outcome identifies the cognitive process dimension.

Table 1. Bloom's Taxonomy—Cognitive Process Dimension

Category	Description
Remembering	Retrieve, recall, and/or recognize specific information or knowledge from memory.
Understanding	Construct meaning from different sources and types of information, and explain ideas and concepts.
Applying	Implement or apply information to complete a task, carry out a procedure through executing or implementing knowledge.
Analysing	Break information into component parts and determine how the parts relate or interrelate to one another or to an overall structure or purpose.
Evaluating	Justify a decision or course of action, problem solve, or select materials and/or methods based on criteria and standards through checking and critiquing.
Creating	Form a coherent functional whole by skillfully combining elements together and generating new knowledge to guide the execution of the work.

Curriculum Design

SCO Structure

Examining the structure of a specific curriculum outcome is necessary to fully understand its intent prior to planning instruction and assessment. The verb(s) in the outcome relates to the expected level and type of thinking (cognitive process). A noun or noun phrase communicates the type of knowledge (i.e., factual, conceptual, procedural, or metacognitive) that is the focus of the outcome.

verb: explain
cognitive process: UNDERSTANDING

CK1.3 explain everyday chemical reactions and their application.

Curriculum Guide Layout

The curriculum guide layout is designed to highlight the critical elements/features of the provincial curriculum required for a given course.

Table 2. Details of Curriculum Guide Layout

Feature	Description
Unit Name	Appears in the upper left hand corner.
SCO Block	Appears in the coloured box; contains the cognitive process level
AI List	Appears in the body of the page immediately following the SCO.
EGC Map	Appears at the bottom of the page.

Curriculum Design

Unit Name (Topic, GCO, Strand, and/or Big Idea

Specific curriculum outcome (SCO)

Specific Curriculum Outcomes (SCOs)

Content Knowledge: Everyday Chemical Reactions

CK 1	*Learners are expected to ...*					
	explain everyday chemical reactions and their applications.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating

Cognitive process level for this particular SCO

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a compare physical and chemical changes;

b explain evidence of chemical change (e.g., colour change, production of gas, temperature change, formation of a precipitate);

c identify reactants and products in word equations;

d describe the factors that affect reaction rate (e.g., surface area, temperature, concentration, catalyst);

e classify substances as acidic, basic, or neutral based on their chemical and physical properties and their role in everyday life (e.g., food, cleaning products, environmental impact); and

f describe neutralization reactions and their applications, such as in medicine (e.g., antacids), environmental science (e.g., acid rain treatment), and industry (e.g., farming).

Set of achievement indicators (AIs)indicating “breadth and depth” of SCO

Citizenship	✓ Critical Thinking	✓ Personal-Career Development	Essential Graduation Competencies
Communication	Technological Fluency	Creativity and Innovation	

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Essential Graduation Competencies Map

Assessment and Evaluation

Assessment and evaluation are integral components of the teaching and learning process. They are continuous activities that are planned for and derived from specific curriculum outcomes (SCOs) and should be consistent with instruction. Effectively planned assessment and evaluation improves and guides future instruction. It also promotes learning, builds confidence, and develops learners' understanding of themselves as learners.

Assessment is the process of gathering evidence about student learning. Assessments need to be reflective of the cognitive process and type of knowledge indicated by the SCO ("Bloom's Taxonomy" on page 9). The achievement indicators inform teachers of the depth and breadth of skills, knowledge, and understandings expected for each SCO.

Learners should know what they are expected to learn as designated by SCOs and the criteria that will be used to determine the quality of their achievement.

Assessment must provide opportunities for learners to reflect on their progress, evaluate their learning, and set goals for future learning.

Assessment has three interrelated purposes:

- assessment for learning to guide and inform instruction (formative)
- assessment as learning to involve learners in self-assessment and setting goals for their own learning (formative)
- assessment of learning to determine learner progress relative to curriculum outcomes (summative)

Triangulation is a process by which a teacher uses evidence about student learning from three different sources. These sources include conversations, observations, and products. Collecting data from a balance of these sources ensures reliable and valid assessment of student learning.

Evaluation involves analysing and reflecting upon various forms of evidence of student learning and making judgments or decisions regarding student learning based upon that evidence.

Effective assessment strategies

- must be valid in that they measure what is intended to be measured and are reliable in that they consistently achieve the same results when used again, or similar results with a similar group of learners;
- are appropriate for the purpose of instruction and learning strategies used;
- are explicit and communicate to learners and parents the expectations and criteria used to determine the level of achievement;
- are comprehensive and enable all learners to have diverse and multiple opportunities to demonstrate their learning consistently, independently, and in a range of contexts in everyday instruction;
- accommodate the diverse learning needs and experiences of the learners;
- allow for relevant, descriptive, and supportive feedback that gives learners clear directions for improvement, and engages learners in metacognitive self-assessment and goal setting that can increase their success as learners; and
- assist teachers in selecting appropriate instruction and intervention strategies to promote the gradual release of responsibility of learning.

Social and Emotional Learning (SEL)

Social and emotional learning is the process through which children and adults acquire and effectively apply the knowledge, attitudes, and skills necessary to understand and manage emotions, set and achieve goals, feel and show empathy for others, establish and maintain positive relationships, and make responsible decisions (Weissberg & Cascarino, 2013).

The benefits of social and emotional learning (SEL) are well-researched. Evidence demonstrates that an education integrated with SEL yields positive outcomes for learners, adults, and school communities. These findings include increased social and emotional skills, academic performance, mental wellness, healthy behaviours, school climate and safety, and positive lifetime outcomes (Durlak et al., 2011).

Learners will experience a sense of belonging and emotional safety when teachers develop a supportive atmosphere where learners feel valued and are encouraged to express their ideas and emotions. While SEL isn't a designated subject like history or math, it must be woven into a school's curriculum and community (Durlak et al., 2011; Wiglesworth et al., 2016). The following five skills provide examples of how social-emotional learning competencies can be incorporated into the curriculum:

Self-Awareness entails the understanding of one's own emotions, personal identity, goals and values. Integrating self-awareness involves planning activities and practices that help learners understand and connect with their thoughts, emotions, and strengths and how they influence behaviour;

Self-Management entails skills and attitudes that help learners to regulate emotions and behaviours. Integrating self-management involves developing learners' organizational skills, resilience, and goal-setting abilities through structured activities, personalized learning plans, and providing consistent feedback;

Social Awareness entails recognizing the perspective of those with the same or different backgrounds and empathizing and feeling compassion. Integrating social awareness involves incorporating diverse perspectives, cultural contexts, and collaboration while encouraging learners to understand and appreciate the broader societal implications of the content they are learning;

Relationship Skills entail the tools to establish and maintain healthy relationships and effectively navigate settings with different social norms and demands. Integrating relationship skills involves fostering collaborative projects, encouraging effective communication and teamwork, and enabling learners to develop positive interpersonal connections that enhance their learning experience; and

Responsible Decision-making entails the knowledge, skills and attitudes to make caring and constructive choices about personal behaviour and social interactions across diverse settings. Integrating responsible decision-making within lessons involves incorporating real-world scenarios, ethical considerations, and critical information analysis to make thoughtful choices.

Supporting English as an Additional Language (EAL) Learners

Multilingual learners add valuable experiences to the classroom. The linguistic knowledge and experiences of English as an additional language (EAL) learners can extend the understanding of the linguistic diversity of all learners. When the language, prior knowledge, and culture of EAL learners are valued, respected, and incorporated into learning, the learning environment is enhanced.

Supportive learning includes classroom practices that affirm cultural values and leverage learners' home language and prior knowledge. Making connections to content and language structures in their home language and English is encouraged when possible. It is also essential that EAL learners make connections between their learning in English and learning in other curricular areas and use learning contexts in other subjects to practice, reinforce, and extend their language skills. Addressing the demands of the subject area and discussing how different forms, styles, and registers of English are used for various purposes will benefit learners. Providing students learning English as an additional language with ample opportunities to use English in communicative ways and designing classroom activities to aid language development through active language use will support their learning.

It's essential to address barriers to equitable instruction and assessment for EAL learners. By providing various ways for them to access content, demonstrate learning, and develop language skills, we can ensure their full participation and contribution to the classroom community. This approach not only benefits EAL learners but also enhances the overall learning environment.

STEAM Problem-Solving Processes

The acronym STEAM represents Science, Technology, Engineering, Art, and Math. STEAM education is a pedagogical approach which provides learners the opportunity to integrate learning associated with these five disciplines while solving meaningful problems.

The original acronym, STEM was introduced in the 1990s by the National Science Foundation. The 'A' was added to STEM in recognition that creative thinking normally associated with art is as necessary as analytical thinking when solving problems in science, engineering, and technology. The ability to think mathematically is also an integral aspect of these three fields.

Problem-solving is an iterative, multi-layered and multi-stepped process that requires flexible thinking patterns (Figure 12). The analytical thinking component involves selecting, gathering, sorting, comparing, and contrasting information. Analytical thinking is convergent thinking which helps to identify and narrow possible solutions. Creative thinking is required to solve broad, open-ended problems that do not have a readily apparent solution and are not single-outcome specific. Creative processes involves divergent thinking or out-of-the-box thinking. A creative thinker may consider solutions that are based on intuition and emotion rather than logic. Creative solutions can also arise from observation, inspiration, and serendipity. STEAM activities are designed to encourage the flexibility to move back and forth between these two cognitive processes. They also support the development of other habits of mind necessary for STEAM such as persistence and resilience.

All five disciplines do not have to be targeted at the same time during a STEAM activity. To obtain the benefit of STEAM-based instruction, the problem presented should not have a readily apparent solution or be single outcome specific. The problem should be open-ended and designed in a way that the learner has more than one possible path to the solution. Productive struggle and reflection should be encouraged.

Table 3. STEAM Problem-solving

Problem-Solving Component	Science	Technology	Engineering	Arts	Mathematics
Nature of Problem	Extending our understanding of the natural world	Developing ways to extend human capacity	Addressing a human need or concern	Expressing and interpreting human perception	Discovering mathematical relationships
Name of Process	Scientific Inquiry	Technology Design	Engineering Design	Creative Process	Mathematical Analysis
Initial Question	What causes...?	How can I…?	How can I make…?	Imagine if…	What is the relationship…?
Solutions and Products	Communications of new knowledge	Digital products, digital processes	Structures, equipment, machines, processes	Aesthetic expression, products, processes	Numerical solutions, equations

STEAM problem-solving processes (i.e., scientific inquiry, technology and engineering design, the creative process, and mathematical analysis) differ in the nature of the question and the solution or product. However, all are based on the generic problem-solving process. All are iterative processes that involve reflection, evaluation, and feedback throughout. All require analytical thinking and creative thinking. The figures below compare the problem-solving processes for science, engineering, art, and math.

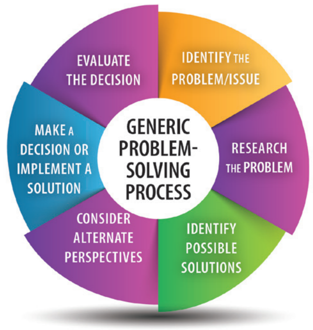

Figure 3. *Generic Problem Solving Process*

Figure 4. *Comparison of STEAM Problem-Solving Processes*

Science Learning Environment

Interdisciplinary Skills

In addition to problem-solving, a number of interdisciplinary skills are required in science.

Mathematical Skills

Mathematics can be considered to be the language of many sciences. Mathematics is used to describe relationships, enable predictions, quantify, and validate evidence. Science provides a concrete context in which learners can develop skills such as mental mathematics and estimation, problem-solving, mathematical reasoning, visualization, and connecting mathematical ideas to the real world. During Grades 7-10 mathematical skills used in science include, but are not limited to

- *measuring and applying appropriate units for quantities such as length, mass, and volume;*
- *performing unit conversions;*
- *solving problems using equations;*
- *expressing patterns and relationships mathematically;*
- *determining totals, averages, percentages, ratios, and proportions;*
- *presenting and interpreting data in graphical and tabular form;*
- *visualizing space and shape from different perspectives.*

Technology Skills

Technology is concerned with developing innovative solutions to problems arising from humans adapting to their environment. Science and technology have been inextricably linked throughout history. Technology is constantly producing new developments that have potential use in science and lead to a greater understanding of our world. New scientific developments, in turn, can inspire further technological innovations.

Technologies used in science include tools and equipment (e.g., thermometers, microscopes) common to science investigations and data gathering, as well as communication and information technologies. Learners should develop skills specific to both forms of technology. Communication and information technologies (CITs) can be used during all steps of the science inquiry process.

Manipulative Skills

Manipulative skills are those skills involved with the handling of equipment and material. Developing confidence in using equipment, materials, and techniques enables learners to explore and inquire in a safe manner while focusing on the concept being investigated rather than "how to." These skills take time to develop and require that learners in Grades 7 to 12 be given frequent opportunities to independently use lab equipment in a risk-free atmosphere. During the intermediate years, learners should develop proficiency in skills and dexterity required when

- *making accurate measurements (e.g., length, mass, volume, time, temperature);*
- *using instruments (e.g., thermometers, multimeters);*
- *selecting and using appropriate glassware for measuring and mixing;*
- *using and caring for instruments, including knowing their use, parts, and adjustments (if applicable);*
- *employing safe practices when using chemicals and equipment;*
- *connecting components, constructing simple apparatuses, and creating simple innovations.*

Science Learning Environment

Data Collection and Analysis

- *Data loggers (e.g., temperature probes, motion detectors) permit learners to collect and analyse data in real time.*
- *Spreadsheets and graphing software can facilitate the analysis and display of learner-collected data or data obtained from databases.*

Visualization and Imaging

- *Simulation/modelling software provides opportunities to create and/or use models to explore concepts that are difficult to visualize, and perform experiments that are unsafe or difficult to perform in the classroom.*
- *Learners may collect their own digital images and video recordings for analysis, or they may access digital images and online video software to help enhance understanding of scientific concepts.*

Communication and Collaboration

- *In addition to the usual tools involved in accessing information, and creating reports and presentations, the Internet can be a means of networking with scientists, teachers, and other learners through social media, cloud computing, blogs, and video conferencing to collect and share information, and work on projects collaboratively.*

Language Skills

Language is the principal means through which learners communicate with others and make meaning of scientific concepts, phenomena, and claims. These skills can be classified in terms of the input and output of information.

The input of information is addressed through reading, listening, and viewing. Learning about scientific concepts, claims, and ideas involves comprehending specialized vocabulary and understanding how to interpret informational texts such as textbooks, magazine articles, lab instructions, and case studies and their features (graphs, charts, tables, and diagrams). Comprehending the intent and purpose of text when evaluating the scientific validity of claims requires the ability to interpret tone and bias, and to determine the logic of arguments.

Figure 5. *The nature of language Arts*

The output of information involves communication by speaking, writing, and representing. The purpose of scientific writing is to communicate new findings so that they can be retested, validated, and expanded upon by other scientists in the global scientific community. The style of writing employed by scientists works to this purpose by being succinct and precise, and by avoiding descriptive and colloquial words that may create bias or not be universally understood. Nomenclature rules (i.e., naming rules) for organisms and chemicals are determined by organizations such as IUPAC (International Union of Pure and Applied Chemistry) and the ICZN (International Commission on Zoological Nomenclature). When learners write scientifically, they not only construct new understanding of the scientific concept being examined, but they also practise the basic principles inherent to the nature of science.

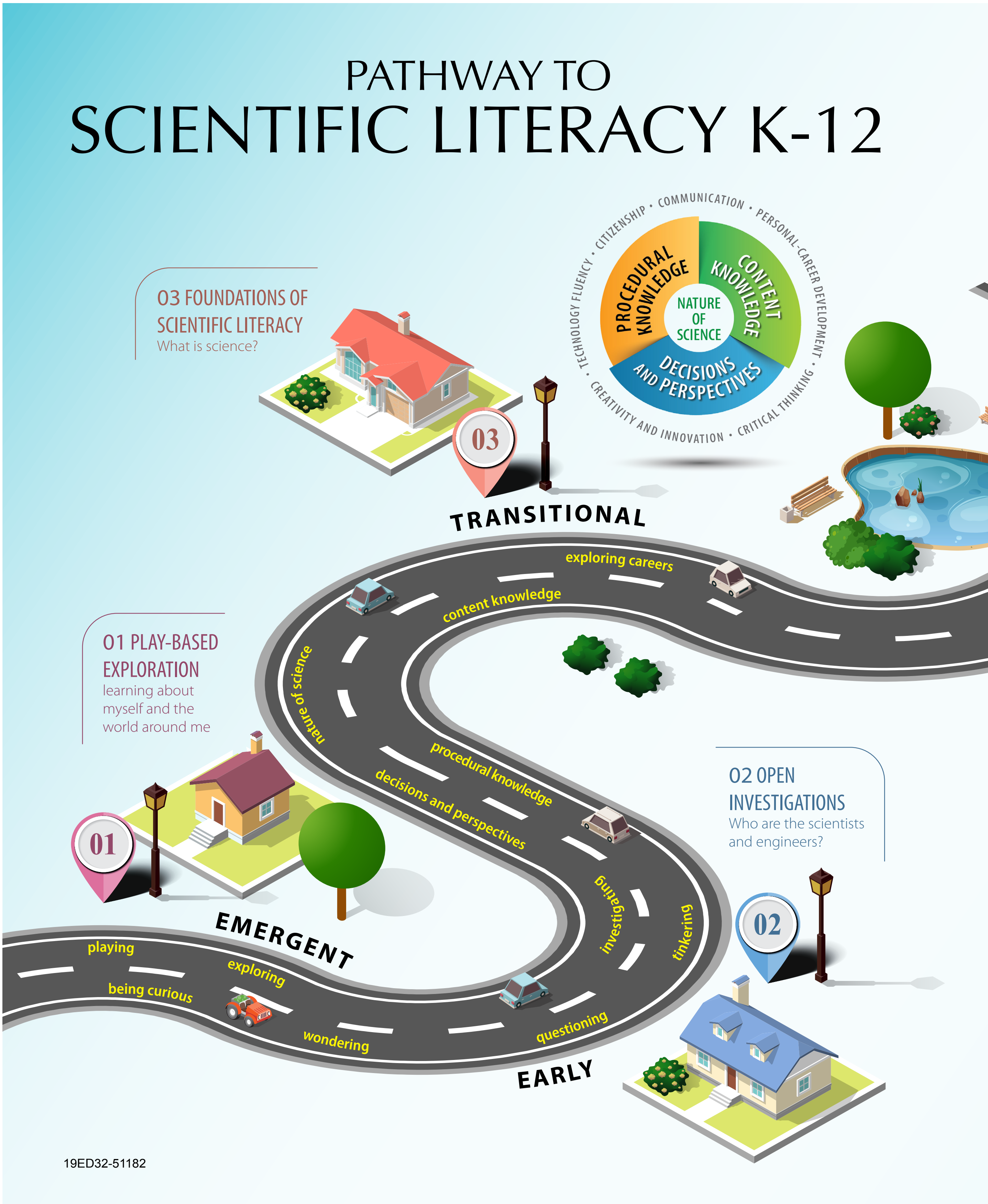

Figure 6. *Pathways to Scientific Literacy*

Pathway to Scientific Literacy

Foundations of Scientific Literacy

Overview

The four foundations of scientific literacy represent the complex and dynamic relationship of science and society that is depicted in Figure 7. How Science Works. Procedural knowledge and the Nature of Science are represented in this model by Exploration and Discovery, Testing Ideas, and Community Analysis and Feedback. The final results of science, Benefits and Outcomes, include the theories, models, and laws that help explain natural phenomena and are addressed by content knowledge. The Benefits and Outcomes section of the model also links to the foundation Decisions and Perspectives, since both relate to the application of science in our society.

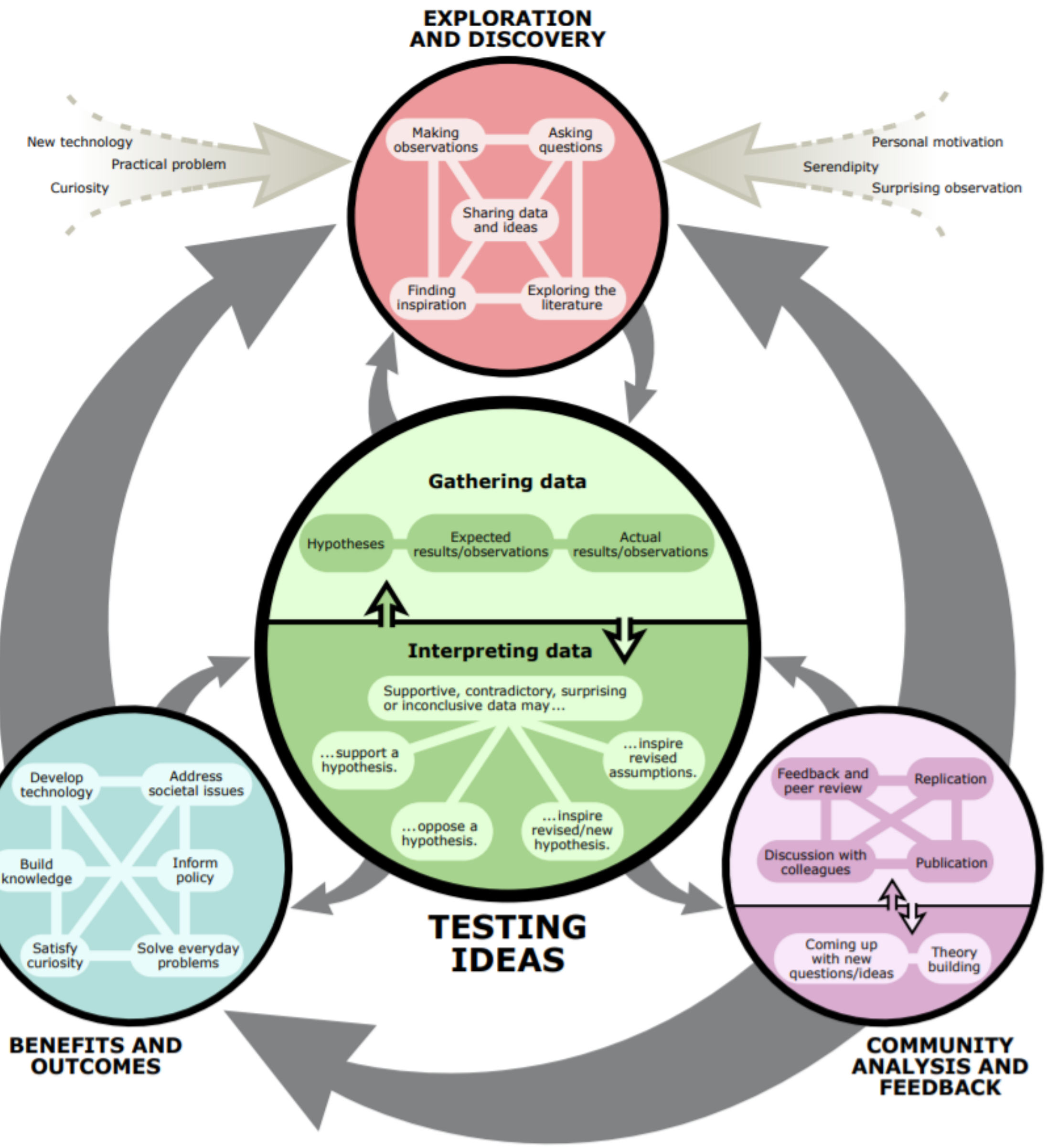

Figure 7. *How Science Works (University of California Museum of Paleontology 2016)*

Nature of Science

What is science?

> *"Epistemic knowledge includes an understanding of the function that questions, observations, theories, hypotheses, models, and arguments play in science, recognition of the variety of forms of scientific inquiry, and the role peer review plays in establishing knowledge that can be trusted." (OECD 2015)*

Science originated as a philosophy of nature, and it stems from the curiosity of humans and their ambition to understand themselves and the natural world around them. Science presumes that the world has a natural organization and is coherent; therefore, it can be understood. From the historical beginnings of science, humans have attempted to explain the natural world around them by looking for patterns, trends, similarities, and differences in everything from structure and composition to properties and behaviours.

The branch of philosophy known as epistemology (theory of knowledge) examines knowledge and the way we come to know. Many ways of knowing have been identified—such as faith, intuition, emotion, perception, memory, imagination, and reason. (Dombrowski, Rotenberg, Brick 2013) Knowing something scientifically involves rational reasoning. It is not the purpose of this science curriculum to rate one way of knowing as superior to another, but instead, enable learners to develop the skills necessary to think scientifically. This begins with an understanding of the characteristics and principles of science.

Science is Limited and Dynamic

Science is limited to developing knowledge and understanding of the physical world. Science can only address questions that have testable solutions; questions such as those relating to the supernatural, ethics, value, or aesthetics are beyond the scope of science.

The body of knowledge that is produced by science is constantly evolving, and much of our understanding of the world has resulted from a steady and gradual accumulation of knowledge over time. Scientists are always proposing and testing new hypotheses, researching, and building bodies of evidence that can lead to new theories.

Science is never absolute but based upon probability and levels of certainty. However, this does not mean that everything we know as a result of science cannot be relied upon or used to make decisions. Many hypotheses are accepted when it can be shown that there is a 95% probability that the results are not found due to chance; the probability of some studies is higher (e.g., 99%) and approaches, but never reaches, 100%. It takes many studies, each stemming from a hypothesis, and each passing through a rigorous review process, before the scientific community supports the acceptance of a new theory. By the time a theory is accepted, often decades of scientific studies have contributed to its acceptance.

Science is Evidence-Based

Although the practices and types of studies used by scientists to interpret and describe our world are quite varied (Figure 9), the knowledge they create is considered scientific when it is based on valid empirical evidence. Empirical evidence is qualitative or quantitative observations (data) recorded using human senses or technology; raw data must be analysed and interpreted before it is considered evidence. The evidence used to support scientific claims may or may not result from experimentation. When evaluating evidence consider the following questions.

Evaluating Evidence

Is it relevant?
Is it plausible?
Is it sufficient?
Is it reliable?
Is there bias?
Is it replicable?

Foundations of Scientific Literacy: Nature of Science

Science Involves Rational Reasoning

The development of scientific claims and theories is characterized by an interplay between inductive and deductive reasoning. Inductive reasoning occurs when generalizations or inferences are made based upon observations. When scientists use generalizations to predict what will happen during a test or experiment, they are practising deductive reasoning. While inferring and inductive reasoning are important aspects of science, learners should recognize that making a conclusion without testing and using deductive reasoning is "jumping to a conclusion" (Figure 6) and is not "scientific thinking." Engaging learners in reasoning and argumentation in defense of their claims or conclusions is central to the development of critical thinking in science

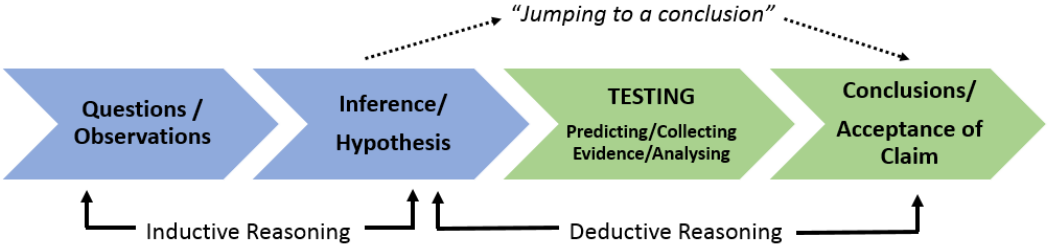

Figure 8. *Scientific Reasoning*

Science Language is Precise

Words commonly used to denote absolutes (e.g., all, none, never) are avoided in scientific communication to reflect that science cannot give complete certainty. Even fact, a statement of absolute truth in lay language, is used differently in science. This is also true for the terms hypothesis, law, and theory.

- A fact is a readily verifiable observation that is generally accepted (e.g., if you drop a coin from your hand, it will fall to the Earth). Facts in science are still open to inquiry and therefore able to change.
- Hypotheses are tentative explanations describing a causal relationship. Hypotheses are not guesses but stem from problems, questions, observations, logic, other hypotheses, and theories. The development of a hypothesis involves elements of curiosity, creativity, imagination, and intuition. Hypotheses lead to predictions of what will happen under a given set of circumstances (i.e., tests or investigations). Hypotheses can be accepted, rejected, or modified as a result of evidence. While hypotheses can never be proven true with 100% certainty, they can be proven to be false. Many varied hypotheses can be generated from one new scientific idea.

> *"Hypotheses are created, not discovered, and the process of their creation is just as open-minded as the process of artistic creation."*
> *(Schick and Vaughn 2014)*

- A law is a descriptive generalization, often mathematical, that concerns patterns of behaviour regarding some aspect of the natural world. Laws differ from theories in that they are not explanations; they are similar in that both can be used to make predictions. It is a misconception that laws evolve from theories. It is also a misconception that laws are more credible than theories because they are definite and cannot be altered. Laws, like theories and hypotheses, can be rejected or modified as new evidence is found.

Examples of Laws

Laws of Thermodynamics
Law of Natural Selection
Ohm's Law
Coulomb's Law
Universal Law of Gravitation

Foundations of Scientific Literacy: Nature of Science

- A scientific theory is more than a passing, tentative suggestion, as is implied by its use in common language. A theory, as it is used by scientists, is a well substantiated explanation for a broad set of phenomena within the natural world. A theory synthesizes hypotheses, laws, principles, and facts from a broad range of studies and can involve a variety of fields. In addition to their ability to predict new and a diverse range of phenomena, theories are evaluated in terms of their ability to be tested, their simplicity (how many assumptions are required), and how well they fit into established scientific understandings. Theories maintain acceptance until disproven.

Examples of Theories

Atomic Theory
Germ Theory of Disease
Big Bang Theory
Theory of Evolution
Theory of General Relativity

Science is a Collaborative, Human Endeavour

The science community is global and includes people of all genders, societies, cultures, and ethnicities. While everyone uses science in some way, it is the members of this community who contribute to our deepening understanding of the world. This is due to the fact that scientific research often requires years of training and access to highly specialized equipment and materials that are not at the disposal of the average citizen.

Science is a collaborative process. The proliferation of information that has been generated by this discipline has heightened the need for specialization in increasingly narrower fields. To compensate for this, scientists often work in teams composed of a number of specialists from a variety of fields. Technology has facilitated this collaboration by eliminating the requirement for team members to work in the same geographical location. Online publishing makes the findings of studies available so that investigations can be repeated, critiqued, or developed in new directions. The rigorous process of critical review is frequently completed by peers who have an expertise within the area being studied. Whether by sharing expertise or by providing feedback, collaboration is an essential aspect of science.

Skills and Attitudes for Collaboration

Considering others' ideas and perspectives
Criticizing ideas, not people
Accepting criticism
Being persuasive
Listening
Showing initiative
Asking for and offering help
Sharing ideas
Being responsible, completing tasks
Taking turns
Clarifying and asking for clarification
Following directions

Procedural Knowledge

What do scientists do?

The focus of many scientific investigations (studies) is to determine the relationship between variables. Of interest to scientists is 1) Is there a relationship? 2) Is the relationship correlational? 3) Is the relationship causal? In correlational relationships, there is an association between the variables. However, it is not known whether or not one causes the other to occur. In causal relationships, one variable results in the response or occurrence of another in a consistent manner. Causal relationships can be complex such as is seen with chain reactions, biofeedback mechanisms, and biosphere nutrient cycles. Understanding cause and effect is an important step towards controlling or modifying the cause in ways that address a human need. Often, when a relationship between two variables is assumed to be causal, it is only correlational. Understanding the difference between these two concepts is a fundamental aspect of scientific literacy.

Examples of No Relationship, Correlational, or Cause and Effect

- Smoking and cancer (Causal)
- Genetically modified organisms (GMOs) and decrease in biodiversity (no Relationship)
- Climate change and human activity (Complex Causal)
- Vaccines and autism (no Relationship)
- Megadoses of vitamins and health (Correlation)

Correlations can be positive or negative. If the correlation is positive, the variables move in the same direction (e.g., an increase in attendance is associated with an increase in achievement). If the correlation is negative, a change in direction of one variable is associated with a change in the opposite direction of the other (e.g., an increase in the number of people vaccinated is associated with a decrease in the incidence of a disease–this is also causal). In science, establishing a correlational relationship requires more than observation and inductive reasoning. It requires data collection and statistical analysis, which are used to determine both the direction and strength of the correlation. (e.g., Pearson's correlation coefficient is calculated to measure the linear relationship between two variables.)

Correlational relationships can appear odd, until one remembers that they do not necessarily represent cause and effect. Two examples that demonstrate this are the positive correlation between smoking and alcoholism, and the positive correlation between ice-cream sales and violent crimes. Ice-cream sales do not cause crime. However, correlation may imply a causal relationship and warrant further examination, as was the case with smoking and lung cancer. Smoking was once thought to be beneficial to health. However, the mass production of cigarettes in the early part of the 20th century soon revealed a positive correlation between smoking and lung cancer. The question remained: was tobacco a causative agent?

Pure causation is extremely hard, and arguably impossible, to prove with 100% certainty. This is due to the fact that real life is complex with a variety of confounding variables that are unable to be completely identified and controlled. Sir Richard Doll and Sir Austin Bradford Hill confirmed the causal link between smoking and cancer in the 1950s. Part of their work involved establishing criteria (Hill's postulates) to increase the strength of causal claims. (Oleckno 2002) The more of these postulates that are true for a given relationship, the more likely it is causal in nature. Tools such as Hill's postulates, together with multiple lines of evidence gathered from examination of 7,000 studies over the following decade, resulted in consensus in 1964 that smoking does cause cancer.

Questions to Help Determine Cause and Effect (based on Hill's postulates)

- Does the cause come before effect?
- What is the strength of association (measured by statistics)?
- Is there a consistent association?
- Is there a mathematical relationship between variables?
- Does it make sense in terms of other established science?

Categories of Scientific Studies

One way to classify scientific inquiries is to divide them into two categories: experimental studies and observational studies (Figure 7). (Oleckno 2002) In experimental studies, the investigator has control over how the variables are manipulated. For example, in a study on the effect of temperature on the rate of a chemical reaction, the experimenter would manipulate the temperature (cause) and measure the responding change in reaction rate (effect). Confounders such as agitation and the type of chemical would be controlled. These forms of causal investigations are frequently equated with "inquiry" in science education. Observational studies, on the other hand, do not include direct manipulation and control of variables by the experimenter. The preferred study design is best determined by the nature of the question.

Randomized, controlled experimental investigations remain the gold-star method for validating cause and effect phenomena. A familiar type of randomized controlled study is one used in drug trials where some subjects are given the experimental drug to see if it causes an effect. For others, the drug (which is the independent variable) is replaced with a placebo; these subjects are the control group and should not experience the effect (dependent variable). If the subject is unaware of which treatment they received, the experiment is considered blind. This helps minimize bias that would reduce the quality of the evidence.

Observational studies can be descriptive or analytical in nature. Descriptive observational studies are not directed by a specific question but involve collecting information that may lead to the development of a hypothesis. Analytical-observational examinations, like experimental inquiries, are designed to answer a proposed question. However, due to ethical considerations, they do not allow for direct experimentation. Analytical-observational studies can still demonstrate causal relationships with a high degree of certainty when tools such as Hill's postulates are used. To improve their ability to determine cause and effect, analytical-observational investigations rely on methods such as careful design (e.g., use of longitudinal studies) and rigorous statistical control. Observational studies are frequently used in medical research, and appear to be the ones that are most often surrounded by controversy in the media, especially when a cause and effect relationship is suggested.

Modelling: Investigating Complex Systems

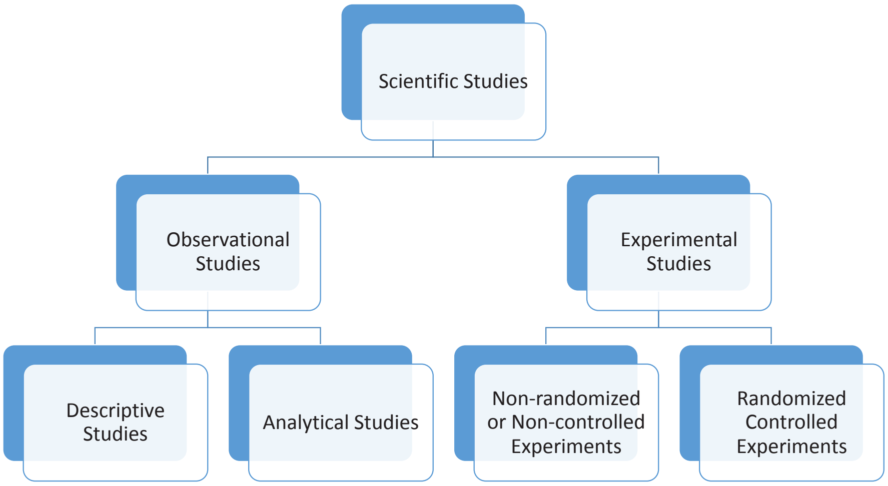

Figure 9. *Classification of Scientific Studies. Adapted from Oleckno, 2002*

Foundations of Scientific Literacy: Procedural Knowledge

Components of Scientific Inquiry

The process of developing scientific knowledge is a complex interplay of experimentation; current knowledge; modification of theories; debate; social, cultural, political, and economic influences; and peer review and acceptance. This observation of science has often resulted in the declaration, “There is no one scientific method.” This statement is true in the sense that there are many ways to inquire or answer scientific questions, but it has seemingly resulted in a misconception in science education that the approach to scientific investigation is vague and that there are no common elements in the way that scientists inquire. While study designs (Figure 9) vary depending on the question being asked, the process of developing new scientific knowledge always involves a number of aspects or stages (Figure 10). These aspects include asking testable questions about the natural world, collecting and analysing evidence to answer those questions in a logical manner, and sharing that knowledge with other experts so that it can be skeptically reviewed and validated by other lines of evidence. Each stage of scientific inquiry is associated with specific skills and competencies (Table 4).

Stages of Scientific Inquiry

Initiating and Planning
Performing and Recording
Analysing and Interpreting Data
Communicating Findings

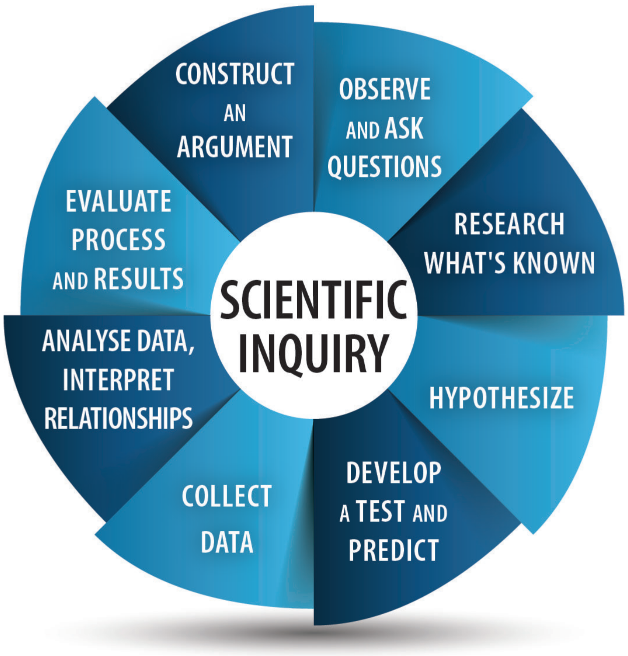

Figure 10. *Scientific Inquiry Process Wheel*

Foundations of Scientific Literacy: Procedural Knowledge

Table 4. Stages of the Scientific Inquiry Process and Selected Skills

Component of Scientific Literacy	Detail	Skills and Competencies
Initiating and Planning (creativity and innovation)	Exploring, tinkering, and asking questions	observing activating prior knowledge brainstorming researching for background information
	Hypothesizing	selecting and refining questions or hypotheses inferring (inductive reasoning), predicting
	Designing and investigating	planning (time, materials, sequence) identifying variables (independent, dependent, control) identifying data to be collected that will help answer the question adapting or developing a procedure performing a trial run
Performing and Recording (manipulative skills and problem-solving)	Performing an investigation and collecting evidence	using equipment and techniques safely or running computer simulations building prototypes, developing models following instructions and sequencing tasks reading digital and analog scales recording quantitative and qualitative data measuring accurately, recording precision of measurement managing time, evaluating progress, problem-solving as necessary collaborating
Analysing and Interpreting Data (higher order/ critical thinking)	Analysing and interpreting evidence	analysing patterns and trends using mathematical processes, knowledge, and skills graphing transforming representations (e.g., graphs ↔ tables, diagrams ↔ text) comparing and contrasting classifying identifying cause and effect, or correlational relationships making conclusions
	Evaluating errors	evaluating scientific errors (degree of reliability and certainty of measurement, and control of variables) reflecting on ways to improve future investigations and data
Communicating Findings (synthesizing, reasoning, argumentation)	Defending and communicating findings	constructing explanations using writing, media, visual literacy, and technology skills to create a product that communicates findings/makes a claim explaining (discussing) results using deductive reasoning, evidence, and argumentation to defend claim (accept or reject a hypothesis)
	Proposing further questions	identifying new questions that arise from the investigation

Foundations of Scientific Literacy: Procedural Knowledge

A system is a collection of components that interact with one another so that the overall effect is much greater than that of the individual components. Examples of systems are educational systems, political systems, transportation systems, the solar system, the respiratory system, electrical systems, mechanical systems, and ecosystems.

> *"Systems thinking is the ability to see the world as a complex system, where everything is connected to everything else." (Sterman 2000)*

Systems thinking is an essential higher order thinking skill that involves thinking about a whole in terms of its parts, and alternatively, about the parts in terms of how they relate to one another and the whole. It involves analysing the components, dynamics, and the interactions within and between systems. Examining systems in terms of stability, equilibrium, and rate of change is a major focus of both science and engineering.

Models are one tool used by scientists and engineers to help them understand natural and material systems. Models facilitate the understanding of abstract ideas and testing of relationships between variables in complex systems. Models, such as the atomic model, are refined as understanding of a phenomenon evolves.

Scientific models can take many forms. Conceptual models include:

- *physical replicas (e.g., model of the cell, landforms, water systems of area)*
- *diagrams that demonstrate the relationship of subatomic particles in the atom (Figure 11)*
- *flow charts that depict energy flow in a food web (Figure 12) or electricity transmission rates (Figure 13)*

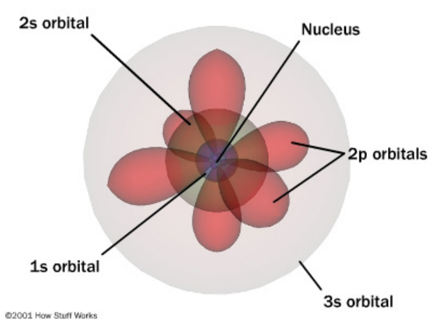

Figure 11. *Quantum Mechanical Model of the Atom*

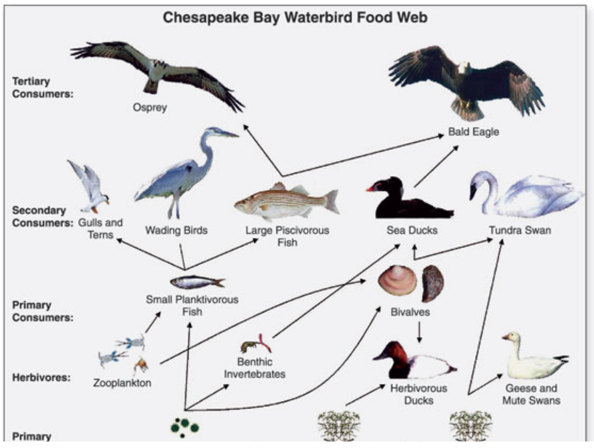

Figure 12. *Energy Flow in a Food Web (Perry 2019)*

Foundations of Scientific Literacy: Procedural Knowledge

Mathematical models can vary from simple mathematical formulas to computer simulations. The latter extends the human capacity to examine processes present in systems that are too complex or abstract to work with in a practical manner (e.g., global warming, climate change, rising sea levels, population dynamics of a species, forest stand growth, behaviour of a brake system prototype). Simulations are computer programs that connect various components (variables) of the system using mathematical relationships. They allow the experimenter to explore "what if" scenarios by giving them the flexibility to control certain variables while changing others. This enables greater understanding of complex interactions within the system and how these interactions impact the whole system. When learners use computer simulations (e.g., Physics Education Technology (Wieman 2016)) to explore cause and effect relationships based on gas laws, or circuit electricity, they are practising science by using models. Learners should be made aware, however, that because models are oversimplifications of real life, they have limited predictive powers.

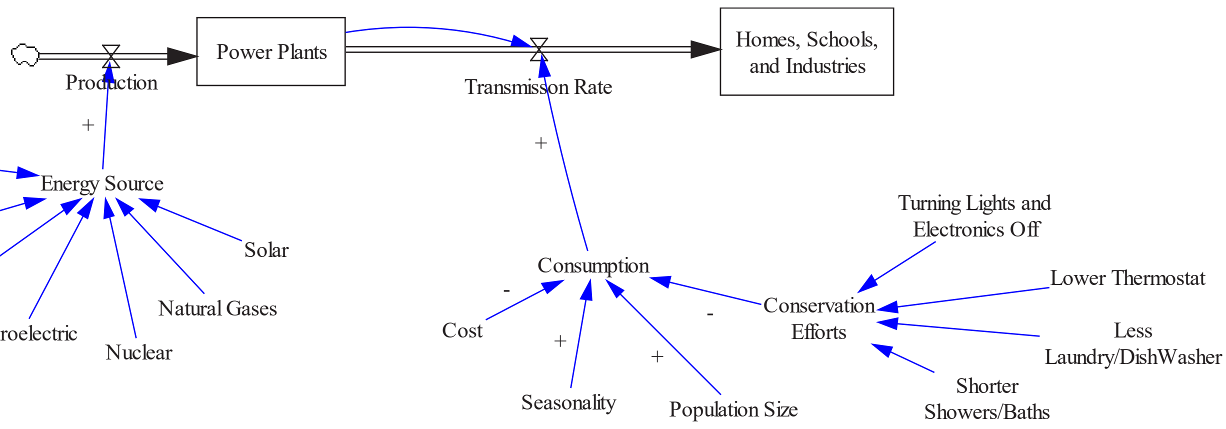

Figure 13. *Stock and Flow Conceptual Model*

Foundations of Scientific Literacy: Content Knowledge

Content Knowledge

What have scientists learned?

There are many fields of science (e.g., chemistry, physics, biology, geology), each of which is associated with specific theories (explanations), models, concepts, and principles. In science education, multiple fields are often grouped under the categories of life science, physical science, and Earth and space science.

Life Science

Life science examines the growth and interactions of life forms within their environments in ways that reflect their uniqueness, diversity, genetic continuity, and changing nature. Life science includes fields of study such as ecology, zoology, botany, cell biology, genetic engineering, and biotechnology.

Physical Science

Physical science, which encompasses chemistry and physics, is concerned with matter, energy, forces, and the relationships between them. Momentum, change, and the conservation laws of mass and energy are addressed by physical science.

Earth and Space Science

Earth and space science bring global and universal perspectives to learners' knowledge. Earth, our home planet, exhibits form, structure, and patterns of change, as does our surrounding solar system and the physical universe beyond it. Earth and space science includes fields of study such as geology, meteorology, and astronomy.

Interdisciplinary Concepts

In addition to the knowledge generated by specific fields of science, there are a number of interdisciplinary concepts that are common to all sciences. For the purpose of this document, these concepts are grouped into five categories: matter; patterns in form and function; energy; cause and effect; and equilibrium, stability, and change within systems. Many of these concepts are not the exclusive domain of science but are also found in mathematics, technology, business, government and politics, education, and law. These themes are fundamental to the conceptual understanding of science and facilitate integrated and higher order thinking by providing a common framework on which learners can organize and scientific knowledge. At every opportunity, these concepts should be taught explicitly within the context of the science topic being studied. Only after accumulating a wealth of examples, illustrations, and experiences will learners integrate knowledge related to these abstract concepts into their thinking and synthesize their understanding of science. A summary of the more important aspects of each of five interdisciplinary concepts follows.

Interdisciplinary Science Concepts

Matter
Patterns in Form and Function
Energy
Cause and Effect
Equilibrium, Stability, and Change within systems

Foundations of Scientific Literacy: Content Knowledge

Matter

The identification, examination, transformation, and cycling of matter within and between systems is of interest to all scientific disciplines. Broad foundational concepts relating to matter include the following:

- All living and non-living entities on the Earth are composed of matter, which has mass and occupies space.
- The smallest unit of matter is the atom.
- Earth's matter is of a finite quantity.
- All matter–including that of plants, animals, elements, and compounds–is formed from various arrangements of atoms; principles that apply to the structure of matter in the physical (inorganic) world also apply to the organic world.
- Atoms are rearranged but not destroyed during chemical change; mass is conserved during chemical change.
- The smallest unit of living matter is the cell; all cells arise from other cells.
- Living matter or "life" is characterized by homeostasis (i.e., regulation of an internal environment), and the ability to metabolize, (i.e., produce energy from chemical reactions), move, grow, reproduce, respond to stimuli, and adapt to the external environment.

Patterns in Form and Function

Form refers to the physical structure, the shape, size, and composition of living and non-living things. Interdisciplinary concepts relating to form and function include the following:

- There is a vast array of living and non-living forms of matter.
- Science classifies matter on the basis of similarities and differences in form (structure) and function.
- There are clear relationships between structure and function in the components of natural and human-made systems. (For example, metallic elements contain atoms arranged in a manner that imparts properties such as conductivity and malleability; anatomical structures such as hollow bones in bird wings support flight.)

Energy

Energy, the ability to do work, is a central concept of science because all physical phenomena and interactions involve energy. Physics describes the interaction of matter and energy at the universal, macroscopic, and atomic levels and uses mathematical models such as the Newton's laws and Einstein's theory of special relativity to explain some of these interactions. Physics is concerned with concepts such as the conservation of energy and its transformation into various forms, motion, and forces. Chemistry focusses on the amount of energy required for chemical reactions to occur and the resulting energy released or absorbed from the surroundings during those reactions (e.g., combustion of fuels). In the life sciences, the flow of energy through individuals and ecosystems controls, maintains, and drives diverse phenomena such as photosynthesis, growth, metabolism, and interactions within food chains. Fundamental concepts relating to energy include the following:

- The sun is the source of radiant energy for the Earth.
- Energy, like matter, can be transferred or transformed, but never created nor destroyed.
- All matter contains energy as a result of its motion (kinetic energy), position (potential energy), or atomic makeup.

Foundations of Scientific Literacy: Content Knowledge

Cause and Effect

Cause and effect has been more thoroughly addressed in "Procedural Knowledge" p.26. Fundamental concepts relating to cause and effect include the following:

- In causal relationships between variables, one variable results in the response or occurrence of another in a consistent manner.
- A major focus of science is identifying, describing, and explaining cause and effect relationships. When possible, these relationships are described mathematically.
- Causal relationships can be complex, such as is seen with chain reactions, biofeedback mechanisms, and biosphere matter cycles.
- Understanding cause and effect helps scientists to predict.
- Correlation does not imply causation.

Equilibrium, Stability, and Change within Systems

A system is an abstract concept that is used in science to describe the part of the universe that is the focus of study. The interaction of components within a system is of interest to all sciences ("Modelling: Investigating Complex Systems" p.27). Fundamental concepts relating to systems include the following:

- A system is a collection of components that interact with one another so that the overall effect is much greater than that of the individual components.
- The boundaries of a system are determined by the observer and vary in scale (i.e., atomic, microscopic, macroscopic, and universal).
- Within living and non-living systems, dynamic (causal) relationships occur that involve changes in matter and energy.
- A system in which all processes of change appear to have stopped, or which displays constancy or stability is in a state known as equilibrium. When at equilibrium, opposing forces or processes balance in a static or dynamic way.
- Systems move towards equilibrium, a state of stability or balance (i.e., lowest potential energy).
- A cause, such as an outside force or an exchange of energy/matter with the surroundings, will cause a stable system to shift away from equilibrium and to exhibit change.
- Change in systems can occur as a steady trend, in a cyclical fashion, irregularly, or in any combination of these patterns.
- It is the rate of change that is often of most interest to scientists, since the rate of change can have a greater impact than the change itself on the stability of a system.
- Scientists use models as tools that facilitate the understanding and testing of relationships between variables in systems.

Decisions and Perspectives

How can science be applied to solve problems?

Science investigates the natural world to develop theories that explain how it works, and laws that describe its patterns of behaviour. Science is not focused on practical outcomes. Instead, technology and engineering apply scientific understanding to propose solutions to human needs or desires. Technology and engineering, like science, are creative human activities with a long history in all cultures of the world. While the three disciplines differ in purpose and methodologies, they are inextricably linked.

The needs addressed by the application of science often arise from humans adapting to and/or modifying their environment. The solutions include new products, processes, systems, or structures. For example, the application of science in agriculture addresses the need to feed an exploding population by developing new equipment, fertilizers, crops, animal breeds, and computer technologies that automate tasks such as feeding and milking. Mechanical, electrical, and civil engineering enable humans to dam and divert water in quantities that enable large-scale irrigation and the production of hydroelectric power. The application of science in medicine has resulted in technologies that detect disease in the early stages; new processes that can repair, replace, and rebuild parts of the human body; medicines that combat pathogens and regulate body functions; and bioengineering techniques that allow us to modify genes and grow new organs in alternative species.

What are the considerations when applying science?

Science is not a matter of opinion. However, decisions regarding how we should apply science, or act upon what we have learned, are based upon opinions that are influenced by various personal, political, cultural, ethical, and economical perspectives. For example, science has resulted in our understanding of chemical and biological principles that enabled the development of pesticides, tools to reduce disease and improve crop yields. However, opinion differs regarding which pesticides to use, when to use them, and in what quantity they should be used. To complicate things further, perspectives shift as our understanding progresses. A case in point is the story of the synthetic pesticide DDT that was developed in the 1940s to combat insect-borne diseases such as malaria. As evidence mounted about this chemical's severe adverse effects on the environment, and predatory birds in particular, there was a call to ban DDT in most countries and to use other pesticides more judiciously.

Decisions that we are required to make vary from personal day-to-day decisions to complex ethical issues that can affect entire species, including our own. As individuals, we make daily choices regarding food, health, and energy, often basing them upon scientific understanding. For example, studies on climate change have created a greater awareness that the burning of fossil fuels (e.g., coal, oil, gasoline) has caused an increase in atmospheric carbon dioxide, which has in turn resulted in climate change. This information has inspired many to consider alternative ways to heat their homes and travel to work. As consumers, our decisions have influenced research and the development of new technologies such as solar panels, windmills, and geothermal heating. As citizens in a democracy, we can influence the development and acceptance of policies, such as the United Nations Kyoto Protocol. Decisions at this level can affect the entire planet.

As science continues to open doors for innovation and the development of new technologies, we will continue to be called upon to make difficult decisions that require weighing the risks and benefits of these advancements. It is important that we teach our learners how to think ethically about the application of science and technology and to consider the question, "Just because we can, should we?" Human ingenuity is frequently accompanied by impacts that can reach far around the globe and long into the future. Therefore, it is imperative for both sustainability and global harmony that we develop scientifically literate, ethical, and critical thinkers who are capable of deciding upon reasonable courses of action, while considering many varying perspectives. This requires that learners have the opportunity to practise flexible thinking, listening to others, questioning, reasoning, and synthesizing their understanding.

SCI401A

SCIENCE

Grade 10 Science

Curriculum Guide

Prince Edward Island
CANADA

Science 401A Course Overview

Course Description

Science 401A provides an opportunity for learners to develop scientific literacy as defined by the four identified foundations: Nature of Science, Procedural Knowledge, Content Knowledge, and Decisions and Perspectives. Content remains an integral part of this course, viewed as the context through which science is learned, helping connect concepts to real-world applications. The content knowledge topics identified as context for Science 401 include Cells and Infectious Disease (life science), Climate Change and Energy Transformation (Earth and space science), Everyday Chemical Reaction (physical science), and Motion (physical science).

Outcome Summary

The outcomes of Science 401A are categorized into four scientific literacy foundations (Nature of Science, Decisions and Perspectives, Procedural Knowledge and Content Knowledge). The table below shows the summary of specific curriculum outcomes for Science 401A.

Table 5. Summary of Curriculum Outcomes

GCO	Code	Specific Curriculum Outcome
Nature of Science; Decisions and Perspectives	NoS 1	evaluate if a reported idea or claim in scientifically reasonable.
	NoS 2	analyse factors that influence decisions to accept scientifically unreasonable claims.
	DP 1	analyse the benefits and risks of scientific and technological developments from multiple perspectives.
Procedural Knowledge	PK 1	apply knowledge and understanding of safe laboratory protocols and procedures.
	PK 2	apply appropriate techniques, procedures, and technologies for collecting and analysing data to solve problems.
	PK 3	use uncertainty in data measurement and data processing.
	PK 4	evaluate scientific phenomena using argumentation.
	PK 5	design an experiment and a prototype.
	PK 6	use appropriate language and visual elements to effectively communicate experimental and design processes.
Content Knowledge	CK 1	explain everyday chemical reactions and their applications.
	CK 2.1	analyse the impact of human activity on climate change.
	CK 2.2	explain sustainable energy solutions used to mitigate climate change.
	CK 3.1	explain why the cell is considered the building block of life.
	CK 3.2	explain the transmission, prevention, and treatment of infectious disease.
	CK 4	analyse motion in a mechanical system.

Science 401A Course Overview

Assessment Framework

The assessment framework describes the relative weighting of each domain (unit or cluster of outcomes) within a specified course. It is constructed by transforming the depth and breadth of each specific curriculum outcome into an overall instructional time for each domain. The primary purpose of the assessment framework is one of validity - to align curriculum outcomes, instruction, and assessment. As such, the framework should be used to ensure that summative learner assessments are representative of the instructional time and complexity of the specific curriculum outcomes for each domain, to inform the specified course reporting structure, and be consulted as a high-level guide for course planning, pacing, and syllabi development.

Table 6. Assessment Framework for SCI401A

Domain/GCO	Remember	Understand	Apply	Analyse	Evaluate	Create	GCO Weight
Nature of Science; Decisions and Perspectives					NoS1		**10%**
				NoS2			
				DP1			
Procedural Knowledge			PK1				**30%**
			PK2				
			PK3				
					PK4		
						PK5	
			PK6				
Content Knowledge		CK1					**60%**
				CK2.1			
		CK2.2					
		CK3.1					
		CK3.2					
				CK4			

Reporting Structure

Nature of Science, Decisions & Perspectives	10
Procedural Knowledge	30
Content Knowledge	60

Nature of Science: Scientific Reasoning

NoS 1	*Learners are expected to ...*					
	evaluate if a reported idea or claim is scientifically reasonable.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
					■	

Achievement Indicators

Learners who have achieved this outcome should be able to …

a identify characteristics of a scientifically reasonable claim (e.g., evidence based, testable, peer-reviewed);

b distinguish between scientific and non-scientific evidence in a given claim;

c use credible sources to verify or refute a reported idea or claim; and

d justify whether a reported idea or claim is scientifically reasonable.

Essential Graduation Competencies		
Citizenship	✓ Critical Thinking	Personal-Career Development
✓ Communication	Technological Fluency	Creativity and Innovation

ELABORATIONS

In this outcome, learners will evaluate if a claim or idea is scientifically reasonable by focusing on the strength and validity of the scientific study behind them. They will move beyond simply accepting information at face value and will begin to critically evaluate the source of information, the strength of the evidence presented, and whether the claim can be supported by scientific methods. The goal is for learners to assess whether claims are based on solid evidence, derived from scientific methodology, and have been scrutinized by the broader scientific community.

When evaluating a claim, learners will examine the data and methodology behind the claim. Key considerations include whether the claim has been tested, whether the sample size is sufficient and representative, whether bias has been controlled for, and whether the findings are consistent with existing scientific knowledge. Learners will also reflect on the level of scrutiny the data has received, especially in terms of peer review and its acceptance by the scientific community.

For example, a claim that relies on evidence from a small sample size or a targeted demographic may be statistically insignificant when generalized to a wider population. Claims that cannot be tested, repeated, or verified by others are scientifically unreasonable and should be treated with caution. To guide this process, teachers may work with learners to co-construct a checklist of criteria similar to that in the table below.

Table 7. Determining if a claim is scientifically valid

Is the Claim Scientifically Valid?	
• Does it focus on the natural world?	• Are there "red flags" in the language used?
• Was it tested? How valid is the evidence (data)?	• Does the claim fit in with well-established science?
• How reliable is the person making the claim?	• What are the possible alternative explanations?
• How reliable is the medium where the claim is made?	• Is the claim embraced by the scientific community?

Learners will develop the critical thinking skills necessary to participate in informed discussions about science in the media, policy, and everyday life. The goal is to develop thoughtful citizens who can identify misinformation, detect bias, and make evidence-informed decisions about science and technology. These skills are essential in a world increasingly shaped by scientific and technological advances, extending far beyond the classroom.

Guiding Questions:

- What are the most essential criteria for deciding whether a scientific claim is credible, and why do some claims seem convincing even when they are not?
- How can we best distinguish between scientific and non-scientific evidence when evaluating a claim?
- What makes a scientific claim most likely to be accepted by the scientific community?

Nature of Science: Factors Influencing Belief

NoS 2	*Learners are expected to ...*					
	analyse factors that influence decisions to accept scientifically unreasonable claims.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
				■		

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a recognize how perspectives are influenced by a variety of factors (e.g., age, gender, culture, socioeconomic, values, beliefs, peer pressure, geographical regions);

b examine factors (e.g., causal illusion, confirmation bias, correlation, risk perception, social media, lack of trust) can influence an individual's decision (e.g., vaccinations, lifestyle, food choices, alternative medical treatments);

c analyse social trends related to the acceptance of explanations that are supported by poor science; and

d describe possible consequences that may result from decisions based on misinformation.

✓ Citizenship	✓ Critical Thinking	Personal-Career Development	Essential Graduation Competencies
Communication	Technological Fluency	Creativity and Innovation	

ELABORATIONS

This outcome emphasizes the development of scientific literacy by examining the personal, social, and cultural factors that influence how individuals and communities interpret and accept scientific information. While science is rooted in evidence and rigorous methodology, the public's response to science is often shaped by belief systems, values, experiences, and biases, rather than by data alone.

Learners will explore how age, gender, cultural background, socioeconomic status, and belief systems can affect how people understand and respond to scientific claims. For instance, risk perception around issues like vaccination, climate change, or genetically modified foods may differ significantly depending on community norms, media narratives, or personal values. They will also investigate how biases such as confirmation bias (seeking information that supports pre-existing beliefs) or causal illusion (assuming causation where there is only correlation) can lead to the rejection of scientifically valid ideas or the acceptance of pseudoscientific ones.

Learners will examine the role of social media, misinformation, and echo chambers in amplifying unscientific perspectives, especially in areas like alternative medicine, vaccine hesitancy, or climate skepticism.
Furthermore, learners will analyse social trends that contribute to the popularization of poor science or pseudoscience, and reflect on the individual and societal consequences of decisions based on misinformation (e.g., health risks, economic costs, loss of trust in science).

Using real-world case studies, media literacy activities, and discussions around current events to help learners understand how scientific information can be misinterpreted or distorted is encouraged. Role-playing, debates, and data analysis tasks can help learners reflect on how decisions are made and what informs those decisions.

Guiding Questions:

- What are the most important personal and social factors that influence people to accept scientifically unreasonable claims, even when credible evidence is available?
- How can we best recognize and resist misinformation?
- What are the most serious consequences of accepting pseudoscience or misinformation?

Decisions and Perspectives: Risks/Benefits

DP 1	*Learners are expected to ...*					
	analyse the benefits and risks of scientific and technological developments from multiple perspectives.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
				■		

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a describe the *Seven Generations Principle* (Haudenosaunee origin) and the application of this lens to study benefits and risks of scientific and technological developments;

b analyse scientific and technological developments for unintended consequences (both positive and negative)

c analyse how societal factors influence scientific and technological developments (may be beneficial to sum but detrimental to others);

d analyse the environmental risks and benefits of applying scientific and technological developments;

e analyse the societal risks and benefits of applying scientific and technological developments; and

f analyse the economic risks and benefits of applying scientific and technological developments.

Essential Graduation Competencies		
✓ Citizenship	✓ Critical Thinking	Personal-Career Development
Communication	✓ Technological Fluency	Creativity and Innovation

ELABORATIONS

This outcome encourages learners to examine scientific and technological developments not only through a scientific lens but also through multiple worldviews, particularly Indigenous ways of knowing. Educators are encouraged to create learning experiences that foster respect for diverse perspectives by incorporating Indigenous voices and worldviews into the classroom. Indigenous knowledge systems are rooted in deep relationships with the land, long-term observations of natural patterns, and a holistic worldview. Using a lens of the *Seven Generations Principle* will prompt learners to consider the options and impacts of their decisions outside of just the current context. Each learner is to think deeply about the decision they are seeking to make, considering what has been done generations before them and how future generations will be impacted. This Indigenous perspectives will engage learners in sustainable decision-making that often contrasts with dominant approaches rooted in industrial growth or short-term gains. Learners will be asked to analyse how historical and ongoing scientific and technological practices have affected, and will affect the economy, environment, and society.

Learners will explore how different communities perceive the risks and benefits of innovations such as renewable energy systems (connection to ***CK 2.1*** and ***CK 2.2***), resource extraction (connection to ***CK 2.1*** and ***CK 2.2***), medical technologies (connection to ***CK 3.2***), or climate interventions (connection to ***CK 2.1*** and ***CK 2.2***). While such developments can bring advances in quality of life and economic opportunity, they may also contribute to ecological degradation, cultural disruption, or deepen existing inequalities.

Learners will explore societal factors, such as power structures, cultural values, access to education, and economic incentives and their influence on the development and application of technology. This allows for learners to develop a broader understanding of innovation and whether something can be done, should be done, and who is impacted by the outcome. Community members could be invited to share local perspectives on science, sustainability, and technological developments. Teachers can guide learners through case studies that explore how historical and current scientific practices have impacted communities. Activities such as debates, reflective writing, or the analysis of competing perspectives on a single issue (e.g., resource extraction or renewable energy projects) can help learners recognize that technological decisions are shaped by culture, ethics, and power.

Guiding Questions:

- If Elders from 150 years ago could share their knowledge, what comments would they make on the current situation? (Rousseau-Thomas)
- If youth from 150 years in the future could identify their priorities, what would they share? (Rousseau-Thomas)
- How can we best decide whether a scientific or technological development should move forward?

Procedural Knowledge: Safety

PK1	*Learners are expected to ...*					
	apply knowledge and understanding of safe laboratory protocols and procedures.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a interpret Workplace Hazardous Materials Information System 2015 (WHMIS 2015) pictograms and labels;

b ensure the safety of self and others by understanding the general safety protocols, procedures, and hazards;

c understand the safety protocols, procedures, and hazards specific to the activity being performed to ensure the safety of self and others; and

d apply appropriate protocols and procedures to acquire, use, and dispose of materials and equipment safely.

Essential Graduation Competencies		
✓ Citizenship	Critical Thinking	✓ Personal-Career Development
Communication	Technological Fluency	Creativity and Innovation

ELABORATIONS

Learners are expected to know their roles and responsibilities, the generic science safety guidelines, and the safety protocols and procedures specific to the science activity as outlined at the beginning of the activity.

Considering the importance of safety in science activities, assessment of this outcome should be frequent and triangulated (observation, conversation, product). This outcome contains a blend of knowing and doing; consequently, assessment should incorporate a variety of assessment techniques, some of which must incorporate performance assessment where learners can demonstrate their knowledge and understanding through application.

Prior to engaging in any laboratory activities, learners should be provided with generic science safety guidelines. These guidelines can be introduced in a variety of creative ways to encourage thoughtful discussion. Learners could engage in co-construction of criteria to relate to the questions, "What matters, what counts, and what is important for a safer science laboratory?" To assist with this process, a series of questions can be created to catalyse learner thoughts on the various aspects of safety in the science laboratory. Furthermore, safety concerns and procedures specific to an activity should be addressed at the beginning of each activity.

WHMIS is a system in Canada that provides information regarding safe use and storage of chemicals in the workplace. WHMIS 2015 aligns these guidelines with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS), which is a world-wide system currently being used. Information regarding WHMIS 2015 and GHS can be found on the website for the Canadian Centre for Occupational Health and Safety (http://www.ccohs.ca).

In grade 9 science (SCI9), learners were introduced to the Workplace Hazardous Materials Information System (WHMIS 2015) through the expectation of applying safe practices when handling and disposing of lab materials. This required that learners would recognise the components of workplace and supplier labels, and safety pictograms, and follow the safety advice provided. The intent of indicator ***PK1a*** is to have learners interpret WHMIS labels and pictograms when the opportunity arises to do so.

Guiding Questions:

- What are the most essential practices in a science lab, and how can we ensure the safety of ourself and others during hands-on investigations?
- What are the most common safety risks in a science lab, and how can we best prepare to prevent them before they happen?

Procedural Knowledge: Experimentation

PK 2	*Learners are expected to ...*					
	apply appropriate techniques, procedures, and technologies for collecting and analysing data to solve problems.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a use appropriate techniques for observation, data collection, and analysis;

b use appropriate data collection tools, including data loggers, for data collection;

c use appropriate data analysis tools, for data analysis; and

d communicate appropriate techniques and procedures needed to investigate scientific phenomena and solve a problem.

Essential Graduation Competencies

Citizenship	Critical Thinking	Personal-Career Development
✓ Communication	✓ Technological Fluency	Creativity and Innovation

ELABORATIONS

This outcome emphasizes the foundational role of scientific practices in solving problems through data-driven inquiry. Learners are expected to engage in investigations that require the application of suitable techniques, procedures, and technologies to gather and interpret data. These may include observation protocols, measurement strategies, the use of data loggers and sensors, as well as tools for organizing, visualizing, and analysing data such as graphs, and spreadsheets. Learners should have hands-on opportunities to use equipment, calibrate instruments, use data loggers or digital sensors, and analyse data.

To have learners critically analyse and engage in inquiry related to this outcome, consider the following pedagogical points that can be easily embedded into every laboratory-based activity.

- **Focus on the 'Why' of the Technique (Procedural Justification)**

Instead of just stating, "Measure the temperature three times," ask: "Why is measuring the temperature three times a better technique than measuring it just once? What specific problem are we trying to solve by using multiple measurements?" This shifts the focus from simply doing the procedure to defending it, leading them to question if the current technique is truly the best way to get the most reliable data.

- **Challenge the Appropriateness of the Tool (Technology Critique)**

Present learners with scenarios where a technology might not be appropriate or could introduce errors. Ask: "We have a thermometer and a high-resolution data logger sensor. When should we use the simple thermometer, and when is the data logger essential? What are the limitations of each device?" This encourages them to view technology not as a perfect black box, but as a tool with specific applications and flaws, driving them to research tool calibration and measurement uncertainty.

- **Introduce Data Anomalies and Ambiguity (Analysis of Uncertainty)**

Do not always provide perfect, clean data sets. Give them data that includes outliers, confounding variables, or unexpected results. Ask: "This data point looks wrong. Is it a mistake in collection, a flawed procedure, or is it a genuine, interesting result? How should we handle it in our analysis?" They learn that data analysis is often an interpretive process rather than a purely mechanical one, requiring them to revisit and potentially redesign their data collection procedures. (Links to PK3)

- **Prioritize Iteration and Refinement (The Iterative Cycle)**

Structure the inquiry as an iterative cycle, not a linear process. After collecting and analysing data, learners should be required to propose specific modifications to their original procedure or technology choices based on their analysis. Ask: "If you were to repeat this investigation, what single change would you make to your technique or tools to improve the reliability of your data, and why?" This fosters a mindset of continuous improvement and methodological critique, which is the hallmark of genuine scientific inquiry. (Links to PK5)

With the initial laboratory-based activity being more formative in nature, teachers can then follow up with post-laboratory summative assessments that focus on how well the learner understood and are able to apply the techniques, procedures, and technologies learned in the laboratory activity.

Guiding Questions:

- How can we determine the best tools and techniques for collecting data, and what happens when we choose the wrong ones?
- What single change would you make to your technique or tools to improve the reliability of your data, and why?
- What simple change can be made to the procedure to reduce the effect of confounding variables?

Procedural Knowledge: Uncertainty

PK 3	*Learners are expected to ...*					
	use uncertainty in data measurement and data processing.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
			■			

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a identify common sources of error in experiments;

b identify the information needed to solve a problem;

c use simple formulae to calculate unknown quantities; and

d estimate reasonable values for quantities.

Essential Graduation Competencies

Citizenship	✓ Critical Thinking	Personal-Career Development
✓ Communication	Technological Fluency	Creativity and Innovation

ELABORATIONS

Learners should understand that uncertainty exists with all measured quantities, and the sources of error fall into one of two categories: random or systematic. They should be able to identify common sources of random and systematic error in laboratory experiments.

Random error results from the imprecision of measuring devices and leads to values measuring above or below the expected value. We often run multiple trials or use more precise equipment to mitigate random error.

Systematic error results from improper experimental setup and leads to values measuring always above or always below the expected value. Examples of systematic error would be a poorly calibrated instrument or a poorly controlled experiment. Multiple trials will not mitigate systematic error.

Evaluating the extent of scientific errors is important, since errors directly impact the quality of evidence used to support the final conclusion. Learners should look for scientific errors that affect accuracy and precision. Scientific errors are accepted as an inherent part of science and reported with the results. Learners should realize that scientific errors differ from mistakes. Mistakes include such things as forgetting to record data, miscalculating, spilling material, and setting up an apparatus incorrectly. In good science practice, investigations in which mistakes have occurred are discarded.

Table 8.Types of Error

Type of Error	Characteristics	Sources of Error	Ways to Reduce
Systematic Error (inaccuracy)	• consistently in one direction • due to design or skill • can be eliminated	• quality of equipment • uncalibrated equipment • failure to control variables • bias (observational)	• improve design or equipment • use a control or blind study • calibrate equipment
Random Error (imprecision)	• fluctuates randomly • can be reduced but not eliminated	• normal fluctuation in measurements • imprecision of instruments used to measure • too few measurements or samples	• use more precise equipment • increase number of trials • increase number of samples

Guiding Questions:

- How can we best reduce sources of error in scientific investigations?
- What purpose does estimation serve?

Procedural Knowledge: Argumentation

PK 4	*Learners are expected to ...*					
	evaluate scientific phenomena using argumentation.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
					■	

Achievement Indicators

Learners who have achieved this outcome should be able to …

a describe the components of scientific argumentation involves (claim, evidence, and reasoning);

b support a claim using evidence from experimental data and associated reasoning;

c support a claim using concepts, models, laws, or theories and associated reasoning;

d argue the directional impact of error on results;

e argue which sources of error most likely had major/minor effects on results;

f explain ways to adjust experimental procedures to mitigate uncertainty or to use controls to strengthen claims; and

g identify the limitations of the evidence provided, including weaknesses in the methodology and possible sources of bias.

Essential Graduation Competencies		
Citizenship	✓ Critical Thinking	Personal-Career Development
✓ Communication	Technological Fluency	Creativity and Innovation

ELABORATIONS

This outcome is central to science, as it touches on all components of the nature of science (how and what we know about the natural/physical world). Argumentation is an important part of how science works. It helps learners understand that science is not just a collection of facts, but a process where ideas are developed and tested using evidence. Scientists use both inductive reasoning (drawing general conclusions from specific observations) and deductive reasoning (applying general principles to predict specific outcomes) to make sense of the world. When learners engage in argumentation, they learn to think critically, use evidence to support their ideas, and understand how scientific knowledge is built and refined over time.

The use of exemplars and gradual release of responsibility for learning are recommended as instructional strategies. Writing frames such as the Claim, Evidence, Reasoning (CER) framework illustrated below can be used to organize evidence and explanation as they relate to the claim. CER is a framework that helps learners construct well-supported scientific explanations. A Claim is a clear statement that answers a scientific question. The Evidence includes data or observations that support the claim, and the Reasoning connects the evidence to the claim using scientific principles. This approach encourages learners to explain their thinking clearly and base their conclusions on data, rather than opinion. CER supports critical thinking and helps learners understand how scientific knowledge is built through logical, evidence-based arguments.

Table 9. Claim, Evidence, and Reasoning Writing Frame Sample

Claim	Evidence	Reasoning
Your answer to a given question is your claim.	The data (evidence) that helped you arrive at your claim is your evidence.	Reasoning is the bridge between your answer (claim) and the data that led you there (evidence).
In the space provided, state your claim, define/describe your evidence, and explain how and/or why your evidence supports or justifies your claim. Together, your claim, evidence, and reasoning form your evidence-based argument.		

Guiding Questions:

- What makes scientific argument most convincing?
- How can we best evaluate the strength of a scientific claim?

Procedural Knowledge: Design

PK 5	*Learners are expected to ...*					
	design an experiment and a prototype.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
				■		

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a formulate relevant questions/problems to investigate;

b formulate hypotheses and make informed predictions;

c identify and control major variables;

d select appropriate procedures/techniques to vary the independent variables;

e select an appropriate sampling procedures/techniques for the dependent variables; and

f build a prototype using an engineering design process.

Essential Graduation Competencies

Citizenship	✓ Critical Thinking	Personal-Career Development
Communication	Technological Fluency	✓ Creativity and Innovation

ELABORATIONS

A fundamental principle of science is that results produced by an investigation are repeatable and reproducible. The table below provides a list of terms that should be used during formal instruction of how to design an experiment.

Table 10. Experimental Design Terms

Repeatable	consistent results when performed by the same individual using the same equipment
Reproducible	consistent results when performed by another investigator using the same equipment
Independent Variable	manipulated or altered variable that causes a change in another variable
Dependent Variable	responding or measured variable that is affected by the independent variable
Controlled Variable	variable that is neither altered nor measured, rather is maintained constant
Confounding Variable	variable that is not properly controlled and can inadvertently affect the results
Hypothesis	a testable explanation to answer a causal question
Prediction	statement describing what is expected to happen during the experiment if the hypothesis is correct

Depending on the topic being studied,learners may engage in designing an entire experimental procedure or choose to modify the design of a component of a study. Learners will decide on a question they wish to investigate and then modify the original procedure to allow for an investigation pertaining to a new inquiry. The table below provides an overview of how to facilitate designing an experiment with learners

Table 11. Independent and Dependent Variables

1. Ask a causal question	2. List possible causes	3. Select an independent variable	4. Identify the dependent variable
What affects the volume of CO_2 gas produced in a yeast solution?	*temperature, amount of yeast, time, amount of sugar, amount of water in yeast solution*	*quantity of sugar*	*volume of CO_2 gas produced*
5. State the hypothesis	**6. Describe the test**	**7. Make a prediction**	**8. Identify variables to Control**
The quantity of sugar affects the volume of CO2 gas produced	*I will vary the grams of sugar put in the yeast solution*	*If I increase the mass of sugar, the volume of CO_2 gas will increase.*	*temperature, amount of yeast, time, amount of water in yeast solution*

Outcome CK 4 offers an entry point to engineering design where learners design a prototype of a mechanical system to perform a specific function. Learners should be familiar with the concept of engineering design from prior grades. It is important to know that while trial and error are part of design, engineers use a systematic process involving iterative phases that include defining the problem, identifying constraints and criteria, researching the problem, brainstorming solutions, and building/testing the prototype.

Guiding Questions:

- Can an experiment be considered effective if it does not lead to a clear solution?
- What are the most important factors to consider when designing a prototype to solve a real-world problem?

Procedural Knowledge: Communication

PK 6	*Learners are expected to ...*					
	use appropriate language and visual elements to effectively collaborate, and to communicate experimental and design processes.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
			■			

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a use appropriate language conventions and visual aids to effectively communicate results;

b use appropriate numeric and symbolic modes of representation to report data and units of measure;

c use an appropriate and consistent method for referencing the works of others;

d listen and ask questions to understand and appreciate the points of view of others; and

e demonstrate a positive attitude towards their work, instructors, and teammates.

✓	Citizenship	Critical Thinking	Personal-Career Development	Essential Graduation Competencies
✓	Communication	Technological Fluency	Creativity and Innovation	

ELABORATIONS

Learners are expected to communicate their understanding of experimental and design processes using language and visual elements that are appropriate to the context of the task. This includes using structured templates to guide their responses and support the development of effective communication skills.

Learners should use appropriate language conventions to effectively communicate. This may include scientific vocabulary, sentence structure, and grammar suited to their current level of proficiency. When appropriate, learners will incorporate visual elements such as diagrams, tables, and graphs that clearly represent data and support the explanation of scientific processes. Visuals should be selected or created in a way that enhances understanding, even if simplified. Learners should represent data using numeric and symbolic formats that are suitable for the task, including correct units of measure and basic scientific notation where applicable.

When referencing sources appropriately and consistently, learners should use a method that aligns with classroom expectations. This may involve simplified citation formats or guided referencing tools to support learners in developing academic integrity.

Guiding Questions:

- What is one way that you could effectively communicate experimental and design processes?
- What important elements are needed to communicate experimental and design processes effectively?

Content Knowledge: Everyday Chemical Reactions

CK 1	*Learners are expected to ...*					
	explain everyday chemical reactions and their applications.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a compare physical and chemical changes;

b explain evidence of chemical change (e.g., colour change, production of gas, temperature change, formation of a precipitate);

c identify reactants and products in word equations;

d describe the factors that affect reaction rate (e.g., surface area, temperature, concentration, catalyst);

e classify substances as acidic, basic, or neutral based on their chemical and physical properties and their role in everyday life (e.g., food, cleaning products, environmental impact);

f describe neutralization reactions and their applications, such as in medicine (e.g., antacids), environmental science (e.g., acid rain treatment), and industry (e.g., farming); and

g name common binary and tertiary ionic compounds given a table of common ions and associated names.

Citizenship	✓ Critical Thinking	✓ Personal-Career Development	**Essential Graduation Competencies**
Communication	Technological Fluency	Creativity and Innovation	

Learners will explore common chemical reactions involving observable changes and real-world connections that they may encounter daily (e.g., cooking, rusting of metal, combustion in engines, neutralization). The focus of this outcome is on making these concepts accessible and relevant to the learners' experiences.
Learners will differentiate between physical and chemical changes to build foundational understandings. Hands-on activities will provide opportunities to observe these changes and classify them as a physical (a transformation where the nature of the substance does not change) or a chemical (a transformation where a new substance is formed). Although it may be relevant to review the types of physical (change of shape, change of state, preparation or separation of a mixture) and chemical changes (synthesis, decomposition, oxidation, combustion), learners do not need to identify or define each type.

With the understanding that a chemical reaction produces a new substance, learners will identify reactants and products given a table of common monatomic and polyatomic ions, and their associated formula. Identifying reaction conditions will provide an entry point to explore why some reactions happen faster than others. Connecting reaction rates to practical examples, such as food spoiling faster in warm temperatures or effervescent tablets reacting faster when crushed, will make the learning more applicable. Providing learners with the ability to formulate and investigate questions related to reaction rate offers opportunities to address PK5.

Learners will examine acids, bases, and neutralization reactions in everyday life. Rather than memorize definitions, learners should engage in hands-on investigations to explore how acids and bases interact with different materials, including testing the pH of substances and categorizing them accordingly. Learners can examine how neutralization reactions – which occur when an acid and a base react to form a neutral solution – play a role in everyday contexts such as medicine (e.g., antacids neutralizing stomach acid), environmental science (e.g., treating acid rain or soil acidity), and industry (e.g., wastewater treatment). Referencing everyday contexts should also serve to provide opportunities for learners to identify career possibilities.

Table 12. Table of Observable Signs in Chemical Changes

Observation	Explanation of why observation indicates a chemical reaction
colour change	A colour change is observed if the substance formed is a different colour than the original reactants. The original substance is not changing colours, as it is no longer present in the quantity observed. What is being observed is a new substance.
formation of bubbles	Bubbles indicate the formation of a gas. A chemical reaction occurs if testing indicates that the gas formed is a new substance. It is not a chemical reaction if the gas formed is the same as the original, such as water vapor from boiling water.
formation of a precipitate	A precipitate is formed when two liquids produce a solid during a chemical reaction. The precipitate is a new substance that is not very soluble.
new odour	An odour indicates a new substance has formed as a gas.
sound	Whenever a chemical reaction occurs, energy is used to break the attractions (i.e., bonds) between atoms and released when these same atoms form other bonds. We observe the difference between energy used and energy produced as heat, light and/or sound. At this level, learners only need to understand that particles are being rearranged, which involves energy.
light	
temperature change	

Guiding Questions:

- What are the most significant ways chemical reactions shape our daily lives, and why do some reactions matter more than others?
- Which clues are the most essential for identifying a chemical change, and why is distinguishing it from a physical change so important in real-world situations?
- What are the best ways to control the speed of a chemical reaction, and how can we use this knowledge in real-world situations?

Content Knowledge: Climate Change & Energy

CK 2.1	*Learners are expected to ...*					
	analyse the impact of human activity on climate change.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a identify the main greenhouse gas (CO_2) and its primary sources;

b identify major human activities that contribute to the production of greenhouse gases;

c explain how greenhouse gases contribute to global warming (greenhouse effect);

d compare Indigenous anecdotes on the environment to observed trends in climate data; and

e describe the observable impact of climate change on Earth (e.g., destruction of habitat, flooding, wildfires, ocean currents, sea level, polar ice melts).

✓ Citizenship	✓ Critical Thinking	Personal-Career Development	Essential Graduation Competencies
✓ Communication	Technological Fluency	Creativity and Innovation	

ELABORATIONS

Human activities, notably burning fossil fuels such as coal, oil, and natural gas, release carbon dioxide (CO_2) into the atmosphere. As a result, CO_2 is the primary greenhouse gas driving climate change. This gas plays a critical role in the greenhouse effect, the process by which gases in the atmosphere trap heat and warm the planet. Human activities that contribute to increased CO_2 emissions include industrial production, transportation (e.g., cars and airplanes), and deforestation.

Learners will explore the impacts of increased greenhouse gases by analysing key climate data, including CO_2 emissions, temperature records, and shifting climate trends. By examining this data, learners can analyse the relationship between human activities and climate change, distinguishing between correlation and causation (connecting to ***NoS1***). For example, learners may recognize and identify patterns and relationships between data sets such as CO_2 emissions and temperature records, suggesting a correlation between CO_2 levels and the increase of global temperatures over time. After identifying correlations, learners will explore the concept of causation. For example, they will examine the scientific understanding of how CO_2 traps heat in the atmosphere, leading to an increase in global temperatures. While CO_2 levels and temperature may correlate, CO_2 is the causal factor in the observed temperature rise. Learners should engage in conducting experiments or online simulations to model the greenhouse effect and visualize heat retention in the atmosphere.

To compare Indigenous anecdotes on climate change with observed trends in climate data, learners can explore the Mi'kmaq practice of ***Netukulimk*** (neh-doo-goo-limgp), the concept of living in balance with the natural world without compromising future generations. Indigenous communities have long observed changes in weather, seasons, animal migrations, and ecosystems through careful relational knowledge passed down over generations. When these perspectives are compared with scientific climate data like temperature records, ice coverage trends, and carbon emissions, learners gain a more holistic understanding of environmental change and the diverse ways of knowing that contribute to climate science. This comparison nurtures cultural respect, critical thinking, and scientific literacy (connecting to ***DP1***). Learners can read or hear stories from Indigenous sources or explore regional case studies such as Inuit observations of sea ice in the Arctic compared to data sets from organizations like NASA.

Observations from Indigenous communities offer an entry point to describing the observable impact of climate change on Earth. Across the globe, rising temperatures have led to a range of visible and measurable changes in the environment. Melting polar ice caps and glaciers have caused sea levels to rise, threatening low-lying coastal regions with flooding and erosion. Changes in precipitation patterns contribute to more frequent and severe storms, while prolonged droughts increase the risk of wildfires and crop failures. Shifts in ocean currents, driven by temperature and salinity changes, disrupt marine ecosystems and weather systems, impacting global biodiversity and food security. Learners can examine case studies and recent events (e.g., increased flooding in coastal communities, wildfires across boreal forests, habitat loss for species like polar bears) to understand how climate change is altering natural systems. This outcome offers an entry point to understanding why some individuals and groups reject scientifically backed climate findings (connecting to ***NoS2***). To make this connection, learners can analyse factors influencing public perception of climate change, including confirmation bias, misinformation spread through social media, lack of trust in science, and political beliefs.

Guiding Questions:

- Which human activities have the most significant impact on climate change, and what evidence best demonstrates their effect on Earth's systems?
- How can different ways of knowing, such as Indigenous knowledge and scientific data, help us understand and respond to climate change?
- What are the most essential skills for thinking critically about climate change information, and why do some people reject even the most credible scientific evidence?

Content Knowledge: Climate Change & Energy

CK 2.2	*Learners are expected to ...*					
	explain sustainable energy solutions used to mitigate climate change.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
		■				

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a identify common forms of energy (e.g., light, heat, mechanical, gravitational, electrical, chemical, nuclear energy);

b compare renewable and non-renewable sources of energy;

c describe sustainable technologies that transform other forms of energy into electrical energy;

d describe sustainable technologies that transform electrical energy into useful forms;

e explain how non-renewable energy can be replaced by technologies that use various energy transformations involving renewable sources; and

f explain ways to reduce energy consumption.

Essential Graduation Competencies		
Citizenship	✓ Critical Thinking	Personal-Career Development
Communication	✓ Technological Fluency	✓ Creativity and Innovation

ELABORATIONS

This outcome aims to equip learners with the knowledge to make informed decisions about energy use, recognize the role of sustainable energy in combating climate change, and think critically about the technologies shaping our future. Learners will learn that there are many forms of energy. Having learners develop a list of energy forms will allow them to explore energy sources, categorize them as renewable and non-renewable, and identify associated technologies. This exploration provides an entry point for ***DP1*** where learners examine the potential societal and environmental risks and benefits of energy technologies.

Rather than focusing on memorization of forms of energy, learners will engage with appropriate language when discussing sustainable energy-related technologies. For example, learners will examine how energy is converted from one form to another and understand how renewable sources transform natural energy into usable electrical power (see Table: Energy Source and Its Transformation to Electrical Power).

To delve further into sustainability, learners can inquire about renewable energy solutions and ways to minimize energy usage. Areas of research may include photovotaic cells, battery storage, grid integration, green hydrogen, electrification of transportation, energy use technologies, and recycling/recycled goods. Learner research can culminate into a collaborative class "docuseries" on sustainable energy solutions used to mitigate climate change. Individual student groups could be responsible in producing a segment of the docuseries with the ultimate goal of educating a target audience.

Table 13. Energy Source and Its Transformation to Electrical Power

	Energy Source	How the energy is transformed into electrical power
Renewable	Solar	Solar panels capture sunlight and convert it into electrical energy through photovoltaic cells
	Wind	Wind turbines convert the kinetic energy of wind into mechanical energy, which is then converted into electrical energy
	Hydropower	Dams or flowing water turn turbines that generate mechanical energy, which is converted into electricity
	Geothermal	Geothermal plants use heat from the Earth to produce steam, which drives turbines to general electrical power
	Biomass	Biomass is burned or converted into biofuels to produce steam, driving turbines which is then used to generate electricity
Non-renewable	Coal	Coal is burned to produce heat, which turns water into steam, driving a turbine connected to a generator
	Natural Gas	Natural gas is burned to produce heat, which turns water into steam, driving a turbine connected to a generator
	Oil	Oil is burned to generate heat, which turns water into steam to drive turbines that generate electricity
	Nuclear	Nuclear fission generates heat, which turns water into steam to drive turbines and generate electricity

Guiding Questions:

- What are the most effective ways to transform renewable energy sources to reduce climate change, and which solutions offer the greatest long-term impact?
- What are the most essential qualities of a truly sustainable energy source, and how do our energy choices reveal what we value as individuals and as a society?
- What are the greatest opportunities and most significant limitations of using technology to replace non-renewable energy, and how can we design the best solutions for people and the planet?

Content Knowledge: Cells and Infectious Disease

CK 3.1	*Learners are expected to ...*					
	explain why the cell is considered the building block of life.					
	Remembering	**Understanding**	Applying	Analysing	Evaluating	Creating

Achievement Indicators

Learners who have achieved this outcome should be able to …

a distinguish between living and non-living things;

b explain the function of major structures in plant and animal cells, including DNA;

c describe the principles of the cell theory; and

d explain why viruses are considered non-living.

Essential Graduation Competencies

Citizenship	✓ Critical Thinking
Personal-Career Development	✓ Communication
Technological Fluency	Creativity and Innovation

ELABORATIONS

This outcome encourages learners to understand the difference between living and non-living things, a foundational concept in biology. Rather than memorizing the characteristics of living things, learners should engage in discussions and observations to explore what makes things alive, encouraging them to develop criteria through inquiry. Guided inquiries should help develop key criteria, such as the ability to grow, reproduce, and respond to the environment. The criteria developed can guide learners in reasoned judgments about whether something is living. For example, while plants, animals, and bacteria meet these criteria, viruses do not because they can not carry out life processes on their own and require a host to reproduce.

Using microscopes to identify major visible structures in plant and animal cells provides an opportunity to assess ***PK1*** and ***PK2***. While observing cells, learners should describe the structures they see (e.g., nucleus, cell membrane, cytoplasm, chromosomes, DNA) and explain their roles in the overall function of a cell. Learners can solidify their understanding in a variety of ways (e.g., cell analogy, interactive walk-through, kinulation, Podcast, animated cell tour).

Table 14. Cell Structures and Function

Cell Structure	Function	Cell Structure	Function
cytoplasm	Contains the contents found within the cell membrane.	chloroplasts (plant cells only)	Absorbs energy from sunlight and convert it to food through photosynthesis.
nucleus	Considered the control center. It contains DNA and controls duplication of cells.	chromosomes	Carry genetic information which is essential for cell division and inheritance.
mitochondria	Considered the power house of the cell. Releases energy from the combustion of glucose.	Nucleolus	Build ribosomes.
cell membrane	Provides support and controls what goes in and out of the cell.	Ribosomes	Reads a strand of DNA (instructions) to build proteins.
cell wall (plant cells only)	Surrounds the cell membrane and provides additional support and protection.	Golgi Apparatus	Finishes, sorts, tags, and ships proteins.
Vacuole	storage container for water, food, enzymes, wastes and pigments	Lysosomes	Little stomach of the cell or a clean up crew to get rid of waste.

A key component of understanding living things is recognizing the principles of cell theory. Learners should explore the three fundamental principles of this theory:
1. All living organisms comprise one or more cells.
2. The cell is the basic unit of life, responsible for all essential life processes.
3. All cells arise from pre-existing cells.

This theory will provide the foundation for understanding why cells are the building blocks of life.

Guiding Questions:

- What are the most essential characteristics of life?
- Which cell structures play the most significant roles in keeping organisms alive, and how do they work together in meaningful ways?
- What is the most significant reason why viruses are considered non-living?

CONTENT KNOWLEDGE: CELLS AND INFECTIOUS DISEASE

CK 3.2	*Learners are expected to ...*					
	explain the transmission, prevention, and treatment of infectious disease.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating

Achievement Indicators

Learners who have achieved this outcome should be able to …

a compare examples of diseases caused by bacteria and viruses;

b describe modes of transmission;

c identify ways to prevent the spread of infectious disease;

d identify ways to treat infectious disease; and

e compare pandemics, epidemics, and endemics.

Essential Graduation Competencies		
✓ Citizenship	Critical Thinking	✓ Personal-Career Development
✓ Communication	Technological Fluency	Creativity and Innovation

ELABORATIONS

In this outcome, learners build on their understanding of infectious disease (bacterial and viral) by exploring the transmission, prevention, and treatment of disease.

Bacteria are living, single-celled organisms (prokaryotes). While some bacteria can cause disease, many play beneficial roles in decomposition, food production (e.g., yogurt, cheese), and medicine (e.g., antibiotics, vaccines). Harmful bacteria can cause diseases such as chlamydia, gonorrhea, syphilis, food poisoning, and Lyme disease.
Viruses are non-living particles that require a host cell to reproduce. Unlike bacteria, they cannot survive independently. Viruses are responsible for diseases like influenza, chickenpox, HIV, and COVID-19.

Table 15. Transmission, Prevention, and Treatment of Disease

Modes of ***transmission***	Public health ***prevention*** strategies	***Treatment*** options
• direct contact (touching, kissing, sexual contact) • indirect contact (contaminated surfaces, shared objects) • airborne transmission (coughing, sneezing) • food and waterborne transmission (contaminated food or water) • vector-borne transmission (bites from misquitoes, ticks, or other animals)	• good hygiene practices (handwashing, covering coughs/ sneezes) • vaccination (to build immunity) • safe food handling (proper cooking and storage) • using protective measures (e.g., masks, condoms) • avoiding contact with infected individuals	• Bacterial infections can be treated with antibiotics, though learners will also discuss the growing issue of antibiotic resistance. • Viral infections can be treated with antiviral medications and supportive care (e.g., rest, fluids, symptom management)

Learners will examine the terms ***pandemic*** (where a disease has spread across countries and continents), ***epidemic*** (where a disease has suddenly and unexpectedly spread within a region), and ***endemic*** (where a disease is present in a stable and predictable way) and use these terms to describe the spread of disease in different geographical areas or populations. They will compare and contrast these concepts, understanding their significance in historical and contemporary contexts.

In an era of abundant digital information, developing critical thinking and scientific literacy are essential skills. This outcome provides an entry point to explore the ***Nature of Science*** as learners will have the opportunity to assess whether an argument related to the transmission, prevention, or treatment of disease is grounded in scientific principles and reasoning. Additionally, learners can identify and describe the potential consequences of decisions based on misinformation.

This outcome also offers an entry point to explore ***DP1*** by having learners analyse the development of medications, such as vaccine and antibiotics, and their impact on public health. Learners will consider the historical and cultural contexts of disease prevention and treatment, including Indigenous approaches to medicine and healing. By examining the benefits and risks of medical advancements, they will explore ethical considerations, accessibility, and the role of traditional knowledge alongside modern science. Through case studies and discussions, learners will develop a deeper appreciation for how different perspectives shape health-related decisions and policies.

Guiding Questions:

- What is the most significant difference between bacterial and viral diseases?
- Which methods of disease prevention are the most essential for protecting public health, and which ones are the least obvious but most effective?
- What is the most significant information we can learn from comparing pandemics, epidemics, and endemics?

CONTENT KNOWLEDGE: MOTION

CK 4	*Learners are expected to ...*					
	analyse motion in a mechanical system.					
	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
				■		

Achievement Indicators

Learners who have achieved this outcome should be able to ...

a describe the motion of an object qualitatively (position, speed, acceleration);

b distinguish between average speed and constant speed (identifying when they are equal);

c perform calculations involving speed (constant, average) of an object using formulas provided; and

d collect data on the motion (position, velocity, acceleration) of a mechanical system using a data logger.

	Citizenship	✓	Critical Thinking		Personal-Career Development	Essential Graduation Competencies
✓	Communication	✓	Technological Fluency		Creativity and Innovation	

ELABORATIONS

Learners will explore motion through qualitative descriptions and quantitative calculations. They will describe motion in terms of position, speed, and acceleration, using everyday language to explain how objects move (e.g., the car is slowing down, the object is moving faster over time). The focus is on building an intuitive understanding of motion before applying mathematical formulas.

For quantitative analysis, learners will use the formulas provided to calculate key motion variables (Table 16). These formulas describe relationships between distance, speed, and time.

Table 16. Formulas to Calculate Key Motion Variables

d = vt	calculates distance when speed and time are known
v = d/t	determines the average speed when distance and time are known
t = d/v	calculates the time required for an object to travel a certain distance at a constant speed

Learners do not have to rearrange formulas but will substitute values to solve for unknowns. These calculations will be applied to real-world motion scenarios through hands-on activities, simulations, and data collection.

To deepen their understanding, learners will use measuring devices for distance and time, including data loggers (e.g., motion sensors) to study kinematics. For instance, they might track the motion of a rolling ball, interpret speed-time data, or compare speed under different conditions. By collecting and analysing real-world data, learners will make connections between theoretical concepts and practical applications

This outcome integrates well with outcome ***PK5***. For the design and build component, learners will apply their knowledge of motion to create a mechanical system that can move or perform a specific function. This component could involve designing a vehicle that travels a certain distance in the shortest time possible. To incorporate an experimental design, learners will identify an independent variable to test (e.g., ramp angle, vehicle mass, surface type) and measure its effect on performance, as measured by the dependent variable (e.g., time), while controlling other variables.

Learners can gather data and apply the provided formulas to analyse the design of an engineered device. They will calculate the speed at various points during the motion and use this information to analyse how well their design performed, where most acceleration occurred, and making adjustments to improve the design efficiency or meet design objectives.

Guiding Questions:

- Which factor (position, speed, distance) provides the most essential insight into how a mechanical system performs?
- What is the best way to improve the motion of a mechanical system?

Appendix A: The Scientific Continuum

The development of the knowledge, skills, and attitudes required for scientific literacy can be described as a continuum with four key stages: emergent, early, transitional, and fluent. These stages are described through the lens of each of the four foundations of scientific literacy; subsequent stages build upon earlier ones. The continuum is based on cognitive developmental patterns for primary, elementary, middle, and high school years with the recognition that learning is neither linear nor mirrored between students.

K–12 Scientific Literacy Continuum		Emergent	Early
Foundations of Scientific Literacy	Nature of Science *What is science?*	• Developing an understanding that we use our senses as a way of knowing • Developing an awareness that science helps us understand the natural and material world	• Developing an awareness of the scientific community that helps us understand the natural and material world • Developing an awareness that scientists follow a process to learn about the world
	Procedural Knowledge *What do scientists do?*	• Using their senses to learn about the natural and material world • Asking questions • Recording and interpreting observations • Playing (exploring and exhibiting curiosity) • Developing manipulative skills • Exploring measurement • Exploring patterns • Exploring similarities and differences	• Exploring the scientific inquiry processes (e.g., questioning, observing, recording, analyzing, interpreting, using models) • Exploring the importance of evidence and variables • Investigating cause and effect • Identifying similarities and differences • Developing more refined understanding of measurement • Exploring design • Using numeric, symbolic, graphical, and linguistic modes to communicate science ideas, plans, and results
	Content Knowledge *What have scientists learned?*	• Identifying characteristics of living things • Exploring properties • Exploring change	• Exploring science topics of personal interest • Developing an appreciation for science and the vastness of its contribution to understanding our world
	Decisions and Perspectives *How should we apply science?*	• Learning to respect self and others • Controlling physical interactions • Collaborating with and listening to others	• Extending focus beyond self and immediate environment • Becoming aware of the benefits and responsibilities associated with science and technology • Becoming aware of personal perspectives related to science issues • Recognizing and demonstrating respect for different perspectives

Appendix A: The Scientific Continuum

Transitional	Fluent
• Developing an understanding of science as a way of knowing (metacognition) • Beginning to develop an understanding of the significance of the processes of science in determining what is, and what is not, science • Beginning to critically think about scientific claims and the consequences of basing decisions on false claims	• Deepening understanding of science as a specific way of knowing that uses rational reasoning • Deepening understanding of the significance of the processes used in science • Demonstrating critical and skeptical thinking when presented with scientific and non-scientific claims in various media
• Discovering order in the natural world by analyzing and describing patterns, with support (e.g., linear and cyclic causal patterns, proportional relationships) • Developing skills for a more systematic approach to scientific inquiry • Developing experiential knowledge of STEAM (science, technology, engineering, art, and mathematics) related design • Developing communication strategies for science (presenting evidence and using reasoning and argumentation) • reflecting about personal skills and character traits that suit STEAM-related careers	• Discovering, recognizing, and analyzing patterns with increasing independence • Using deeper, more thorough, analysis and evaluation of design and scientific error • Performing experimental and engineering design with greater independence • Developing formalized communication strategies for science with more rigorous, logical argumentation and reasoning • Examining science career opportunities
• Developing a framework of understanding regarding the interdisciplinary concepts of science (matter, patterns in form and function, energy, equilibrium, change, systems, and models) and the interconnectedness of sciences and other STEAM fields	• Developing an understanding of foundational concepts within specialized core science (i.e., biology, chemistry, and physcis) and applied science fields (e.g., agriscience, oceanography)
• Reflecting on the risks and benefits of scientific and technological developments • Deepening an understanding of perspectives • Considering other perspectives when making decisions about the applications of science	• Critically thinking about the outcomes and applications of science with consideration of ethics • Making thoughtful decisions regarding science and technology issues • Critically evaluating perspectives using divergent and convergent thinking

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