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Acknowledgements ii
Introduction 1
Using this Curriculum 2
Grades 10-12 Science Framework 3
Core Curriculum 4
Broad Areas of Learning 4
    Lifelong Learners 4
    Sense of Self, Community, and Place 4
    Engaged Citizens 5
Cross-curricular Competencies 5
    Developing Thinking 5
    Developing Identity and Interdependence 5
    Developing Literacies 5
    Developing Social Responsibility 5
Aim and Goals 6
Inquiry 7
    Creating Questions for Inquiry in Science 9
    Science Challenges 10
An Effective Science Education Program 11
    Foundations of Scientific Literacy 13
    Learning Contexts 17
    The Language of Science 20
    Laboratory Work 21
    Safety 23
    Technology in Science 25
Outcomes at a Glance 26
Outcomes and Indicators 27
Assessment and Evaluation of Student Learning 35
Glossary 36
References 42
Feedback Form 45

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Physical Science 20

Introduction

Science is a required area of study in Saskatchewan's Core Curriculum. The purpose of this curriculum is to outline the provincial requirements for *Physical Science 20*.

This curriculum provides the intended learning outcomes that *Physical Science 20* students are expected to achieve in science by the end of the course. Indicators are included to provide the breadth and depth of what students should know and be able to do in order to achieve the learning outcomes.

This renewed curriculum reflects current science education research and updated technology and is responsive to changing demographics within the province. This curriculum is based on the Pan-Canadian Protocol for Collaboration on School Curriculum *Common Framework of Science Learning Outcomes K to 12* (Council of Ministers of Education, Canada [CMEC], 1997).

This curriculum includes the following information to support science instruction in Saskatchewan schools:

- connections to Core Curriculum, including the Broad Areas of Learning and Cross-curricular Competencies;
- the K-12 aim and goals for science education;
- characteristics of an effective science program;
- *Physical Science 20* outcomes and indicators;
- sample assessment and evaluation criteria related to outcomes in science; and
- a glossary.

Inquiry into authentic student questions generated from student experiences is the central strategy for teaching science.

(National Research Council [NRC], 1996, p. 31)

Using this Curriculum

Outcomes describe the knowledge, skills and understandings that students are expected to attain by the end of a particular course.

Outcomes are statements of what students are expected to know and be able to do by the end of a grade or secondary level course in a particular area of study. Therefore, all outcomes are required. The outcomes provide direction for assessment and evaluation, and for program, unit and lesson planning.

Critical characteristics of an outcome include the following:

- focus on what students will learn rather than what teachers will teach;
- specify the skills and abilities, understandings, knowledge and/or attitudes students are expected to demonstrate;
- are observable, assessable and attainable;
- are written using action-based verbs and clear professional language (educational and subject-related);
- are developed to be achieved in context so that learning is purposeful and interconnected;
- are grade and subject specific;
- are supported by indicators which provide the breadth and depth of expectations; and,
- have a developmental flow and connection to other grades where applicable.

Indicators are a representative list of what students should know or be able to do if they have attained the outcome.

Indicators are representative of what students need to know and/or be able to do in order to achieve an outcome. When teachers are planning for instruction, they must comprehend the set of indicators to understand fully the breadth and the depth of learning related to a particular outcome. Based on this understanding of the outcome, teachers may develop their own indicators that are responsive of students' interests, lives and prior learning. These teacher-developed indicators must maintain the intent of the outcome.

Within the outcomes and indicators in this curriculum the terms "including", "such as" and "e.g.," commonly occur. Each term serves a specific purpose:

- The term "including" prescribes content, contexts or strategies that students must experience in their learning, without excluding other possibilities. For example, an indicator might say that students should communicate information about the properties and characteristics of waves using appropriate terminology, including medium, pulse, vibration, cycle, periodic motion, frequency, period, amplitude, phase and wavelength. This means that, although other terminology can be used, it is mandatory to use the listed terms.
- The term "such as" provides examples of possible broad categories of content, contexts or strategies that teachers or students may choose, without excluding other possibilities. For example, an indicator might include the phrase "such as natural vibrations, forced vibrations, resonance and harmonics in

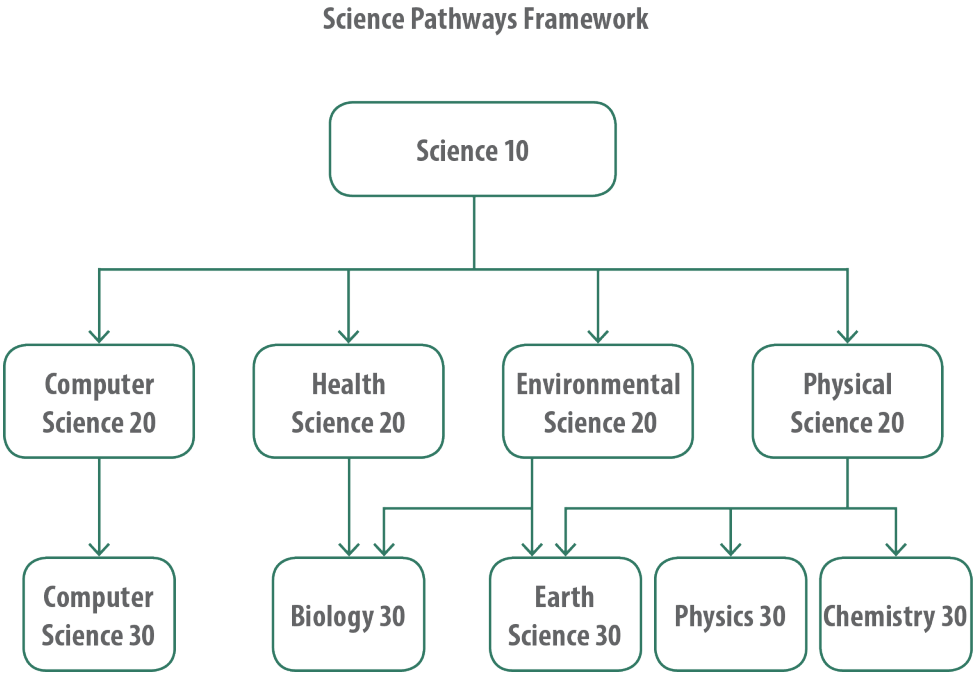
the context of musical instruments and human hearing." This statement provides teachers and students with possible phenomena to consider, while not excluding other phenomena.

- Finally, the term "e.g.," offers specific examples of what a term, concept or strategy might look like. For example, an indicator might include the phrase "e.g., methane, propane, octane and ethanol" to refer to examples of common fuels in combustion reactions.

Grades 10-12 Science Framework

Saskatchewan's grades 10 to 12 science courses incorporate core ideas from the Pan-Canadian Protocol for Collaboration on School Curriculum *Common Framework of Science Learning Outcomes K to 12* (CMEC, 1997). Saskatchewan has developed science courses at Grade 11 that provide students with opportunities to learn core biology, chemistry and physics disciplinary ideas within interdisciplinary contexts. Students should select courses based on their interests and what they believe will best fit their needs after high school.

The chart below visually illustrates the courses in each pathway and their relationship to each other.



Each course in each pathway is to be taught and learned to the same level of rigour. No pathway or course is considered "easy science"; rather, all pathways and courses present "different sciences" for different purposes.

Students may take courses from more than one pathway for credit. The current credit requirements for graduation from Grade 12 are one 10-level credit and one 20-level credit in science.

Core Curriculum

Core Curriculum is intended to provide all Saskatchewan students with an education that will serve them well regardless of their choices after leaving school. Through its various components and initiatives, Core Curriculum supports the achievement of the Goals of Education for Saskatchewan. For current information regarding Core Curriculum, please refer to the *Registrar's Handbook for School Administrators* found on the Government of Saskatchewan website. For additional information related to the various components and initiatives of Core Curriculum, please refer to the Government of Saskatchewan website for curriculum policy and foundation documents.

The Broad Areas of Learning and Cross-curricular Competencies connect the specificity of the areas of study and the day-to-day work of teachers with the broader philosophy of Core Curriculum and the Goals of Education for Saskatchewan.

Broad Areas of Learning

There are three Broad Areas of Learning that reflect Saskatchewan's Goals of Education. Science education contributes to student achievement of the Goals of Education through helping students achieve knowledge, skills and attitudes related to these Broad Areas of Learning.

Lifelong Learners

Related to the following Goals of Education:

- *Basic Skills*
- *Lifelong Learning*
- *Self Concept Development*
- *Positive Lifestyle.*

Students who are engaged in constructing and applying science knowledge naturally build a positive disposition towards learning. Throughout their study of science, students bring their curiosity about the natural and constructed world, which provides the motivation to discover and explore their personal interests more deeply. By sharing their learning experiences with others, in a variety of contexts, students develop skills that support them as lifelong learners.

Sense of Self, Community, and Place

Related to the following Goals of Education:

- *Understanding & Relating to Others*
- *Self Concept Development*
- *Positive Lifestyle*
- *Spiritual Development.*

Students develop and strengthen their personal identity as they explore connections between their own understanding of the natural and constructed world and perspectives of others, including scientific and Indigenous perspectives. Students develop and strengthen their understanding of community as they explore ways in which science can inform individual and community decision making on issues related to the natural and constructed world. Students interact experientially with place-based local knowledge to deepen their connection to and relationship with nature.

Engaged Citizens

As students explore connections between science, technology, society and the environment, they experience opportunities to contribute positively to the environmental, economic and social sustainability of local and global communities. Students reflect and act on their personal responsibility to understand and respect their place in the natural and constructed world, and make personal decisions that contribute to living in harmony with others and the natural world.

Related to the following Goals of Education:

- *Understanding & Relating to Others*
- *Positive Lifestyle*
- *Career and Consumer Decisions*
- *Membership in Society*
- *Growing with Change.*

Cross-curricular Competencies

The Cross-curricular Competencies are four interrelated areas containing understandings, values, skills and processes which are considered important for learning in all areas of study. These competencies reflect the Common Essential Learnings and are intended to be addressed in each area of study at each grade.

Developing Thinking

Learners construct knowledge to make sense of the world around them. In science, students develop understanding by building and reflecting on their observations and what is already known by themselves and others. By thinking contextually, creatively and critically, students develop deeper understanding of various phenomena in the natural and constructed world.

K-12 Goals for Developing Thinking:

- *thinking and learning contextually*
- *thinking and learning creatively*
- *thinking and learning critically.*

Developing Identity and Interdependence

This competency addresses the ability to act autonomously in an interdependent world. It requires the learner to be aware of the natural environment, of social and cultural expectations and of the possibilities for individual and group accomplishments. Interdependence assumes the possession of a positive self-concept and the ability to live in harmony with others and with the natural and constructed world. In science, students examine the interdependence among living things within local, national and global environments and consider the impact of individual decisions on those environments.

K-12 Goals for Developing Identity and Interdependence:

- *understanding, valuing and caring for oneself*
- *understanding, valuing and caring for others*
- *understanding and valuing social, economic and environmental interdependence and sustainability.*

Developing Literacies

Literacies are multi-faceted and provide a variety of ways, including the use of various language systems and media, to interpret the world and express understanding of it. Literacies involve the evolution of interrelated knowledge, skills and strategies that facilitate an individual's ability to participate fully and equitably in a variety of roles and contexts – school, home, and local and global communities. In science, students collect, analyze and represent their ideas and understanding *communicating meaning using* of the natural and constructed world in multiple forms.

K-12 Goals for Developing Literacies:

- *developing knowledge related to various literacies*
- *exploring and interpreting the world through various literacies*
- *expressing understanding and*

various literacies.

Developing Social Responsibility

K-12 Goals for Developing Social Responsibility:

- *using moral reasoning processes*
- *engaging in communitarian thinking and dialogue*
- *taking social action.*

Social responsibility is how people positively contribute to their physical, social, cultural and educational environments. It requires the ability to participate with others in accomplishing shared or common goals. This competency is achieved by using moral reasoning processes, engaging in communitarian thinking and dialogue and taking social action. Students in science examine the impact of scientific understanding and technological innovations on society.

Aim and Goals

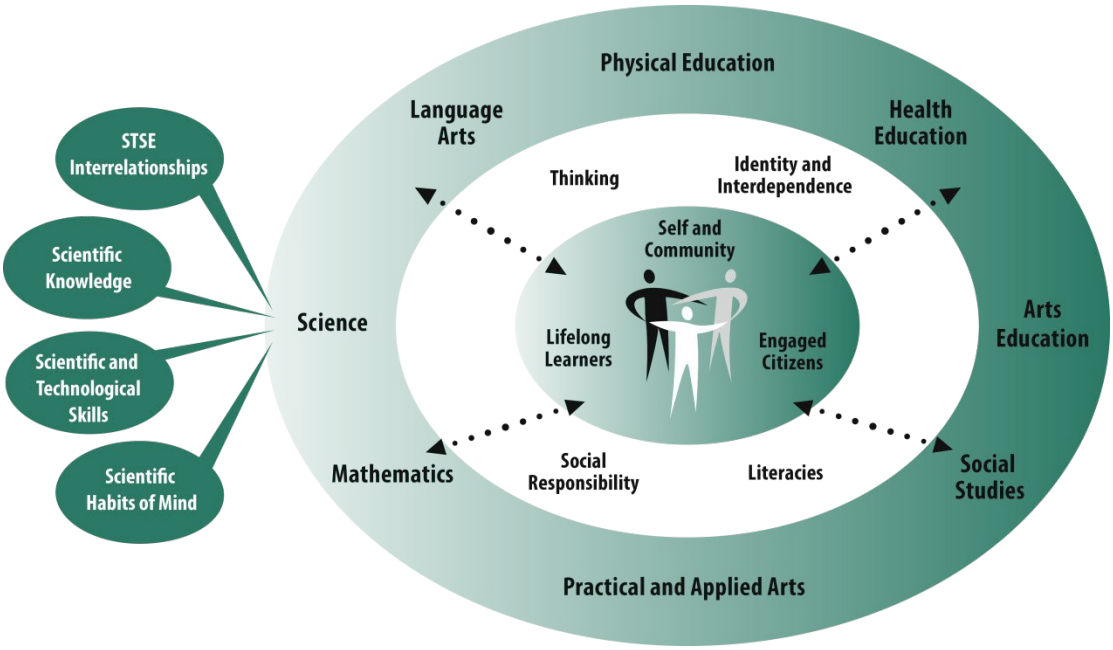
The aim of K-12 science education is to enable all Saskatchewan students to develop scientific literacy. Scientific literacy today embraces Euro-Canadian and Indigenous heritages, both of which have developed an empirical and rational knowledge of nature. A Euro-Canadian way of knowing about the natural and constructed world is called science, while First Nations and Métis ways of knowing nature are found within the broader category of Indigenous knowledge.

Diverse learning experiences based on the outcomes in this curriculum provide students with many opportunities to explore, analyze, evaluate, synthesize, appreciate and understand the interrelationships among science, technology, society and the environment (STSE) that will affect their personal lives, their careers and their future.

Goals are broad statements identifying what students are expected to know and be able to do upon completion of the learning in a particular area of study by the end of Grade 12. The four goals of K-12 science education are to:

- **Understand the Nature of Science and STSE Interrelationships** – Students will develop an understanding of the nature of science and technology, their interrelationships and their social and environmental contexts, including interrelationships between the natural and constructed world.
- **Construct Scientific Knowledge** – Students will construct an understanding of concepts, principles, laws and theories in life science, in physical science, in earth and space science and in Indigenous knowledge of nature and then apply these understandings to interpret, integrate and extend their knowledge.
- **Develop Scientific and Technological Skills** – Students will develop the skills required for scientific and technological inquiry, problem solving and communicating, for working collaboratively, and for making informed decisions.
- **Develop Attitudes that Support Scientific Habits of Mind** – Students will develop attitudes that support the responsible

acquisition and application of scientific, technological and Indigenous knowledge to the mutual benefit of self, society and the environment.



Inquiry

Inquiry learning provides students with opportunities to build knowledge, abilities and inquiring habits of mind that lead to deeper understanding of their world and human experience. Inquiry is more than a simple instructional method. It is a philosophical approach to teaching and learning, grounded in constructivist research and methods, which engages students in investigations that lead to disciplinary and interdisciplinary understanding.

Inquiry builds on students' inherent sense of curiosity and wonder, drawing on their diverse backgrounds, interests and experiences. The process provides opportunities for students to become active participants in a collaborative search for meaning and understanding.

Inquiry is intimately connected to scientific questions – students must inquire using what they already know and the inquiry process must add to their knowledge.

(NRC, 2000, p. 13)

Secondary students who are engaged in inquiry in science should be able to:

- identify questions and concepts that guide scientific investigations.
- design and conduct scientific investigations.
- use technology and mathematics to improve investigations and communications.
- formulate and revise scientific explanations and models using logic and evidence.
- recognize and analyze alternative explanations and models.
- communicate and defend a scientific argument.

(NRC, 1996, pp. 175, 176)

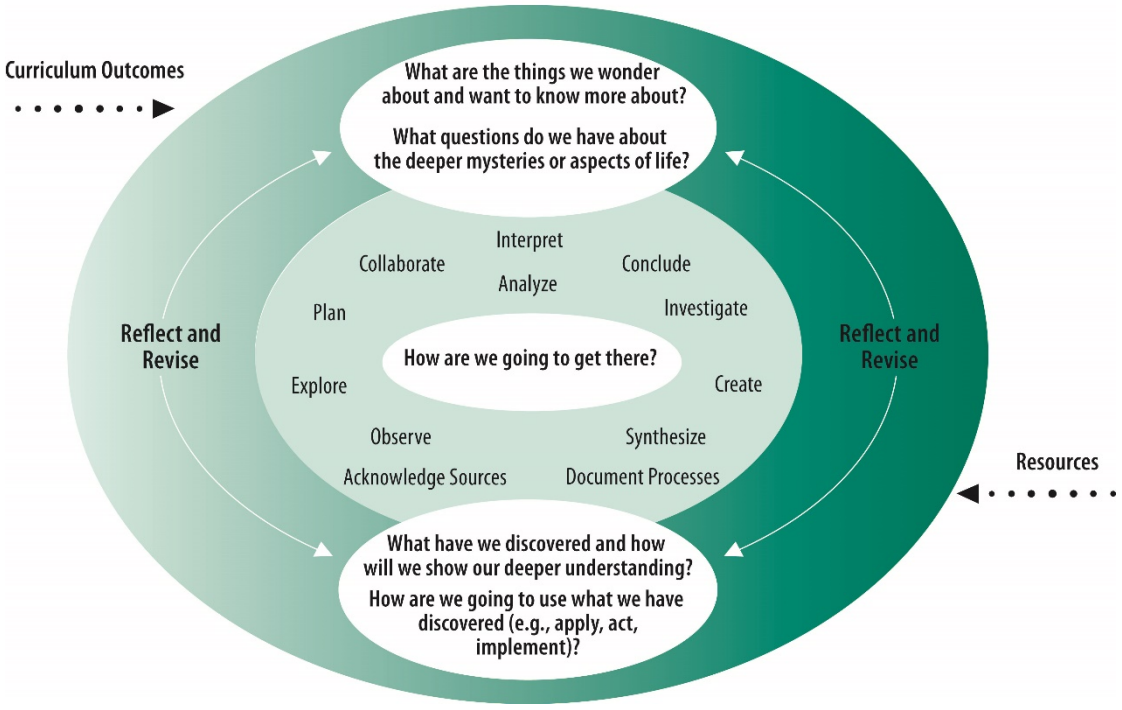
Students do not come to understand inquiry simply by learning words such as "hypothesis" and "inference" or by memorizing procedures such as "the steps of the scientific method".

(NRC, 2000, p. 14)

An important part of any inquiry process is student reflection on their learning and the documentation needed to assess the learning and make it visible. Student documentation of the inquiry process in science may take the form of works-in-progress, reflective writing, journals, reports, notes, models, arts expressions, photographs, video footage or action plans.

Inquiry learning is not a step-by-step process, but rather a cyclical process, with various phases of the process being revisited and rethought as a result of students' discoveries, insights and construction of new knowledge. Experienced inquirers will move back and forth among various phases as new questions arise and as students become more comfortable with the process. The following graphic shows various phases of the cyclical inquiry process.

Constructing Understanding Through Inquiry



Creating Questions for Inquiry in Science

Inquiry focuses on the development of questions to initiate and guide the learning process. Students and teachers formulate questions to motivate inquiries into topics, problems and issues related to curriculum content and outcomes.

Well-formulated inquiry questions are broad in scope and rich in possibilities. Such questions encourage students to explore, observe, gather information, plan, analyze, interpret, synthesize, problem solve, take risks, create, conclude, document, reflect on learning and develop new questions for further inquiry.

Good science inquiry provides many entry points – ways in which students can approach a new topic – and a wide variety of activities during student work.

(Kluger-Bell, 2000, p.48)

In science, teachers and students can use the four learning contexts of Scientific Inquiry, Technological Problem Solving, STSE Decision Making, and Cultural Perspectives (see Learning Contexts section of this document for further information) as curriculum entry points to begin their inquiry. The process may evolve into interdisciplinary learning opportunities reflective of the holistic nature of our lives and an interdependent global environment.

Developing questions evoked by student interests has the potential for rich and deep learning. These questions are used to initiate and guide the inquiry and give students direction for investigating topics, problems, ideas, challenges or issues under study.

The process of constructing questions for deep understanding can help students grasp the important disciplinary or interdisciplinary ideas that are situated at the core of a particular curricular focus or context. These broad questions lead to more specific questions that can provide a framework, purpose and direction for the learning activities in a lesson, or series of lessons, and help students connect what they are learning to their experiences and life beyond school.

Essential questions that lead to deeper understanding in science should:

- *center on objects, organisms and events in the natural world;*
- *connect to science concepts outlined in the curricular outcomes;*
- *lend themselves to empirical investigation; and,*
- *lead to gathering and using data to develop explanations for natural phenomena.*

(NRC, 2000, p. 24)

Questions give students some initial direction for uncovering the understandings associated with a unit of study. Questions can help students grasp the big disciplinary ideas surrounding a focus or context and related themes or topics. They provide a framework, purpose and direction for the learning activities in each unit and help students connect what they are learning to their experiences and life beyond the classroom. Questions also invite and encourage students to pose their own questions for deeper understanding.

Science Challenges

Science challenges, which may include science festivals, science fairs, science leagues, science Olympics, science Olympiads or talent searches, are instructional methods suitable for students to undertake to achieve curricular outcomes. Teachers may incorporate science challenge activities as an integral component of the science program or treat them similar to other extracurricular activities such as school sports and clubs. Teachers undertaking science challenges as a classroom activity should consider these guidelines, adapted from the National Science Teachers Association (NSTA) position statement *Science Competitions* (1999):

- Student and staff participation should be voluntary and open to all students.
- Emphasis should be placed on the learning experience rather than the competition.
- Science competitions should supplement and enhance other learning and support student achievement of curriculum outcomes.
- Projects and presentations should be the work of the student, with proper credit given to others for their contributions.
- Science competitions should foster partnerships among students, the school and the science community.

Science challenge activities may be conducted solely at the school level, or with the intent of preparing students for competition in one of the regional science fairs, perhaps as a step towards the Canada-Wide Science Festival. Although students may be motivated by prizes, awards and the possibility of scholarships, teachers should emphasize that the importance of doing a science fair project includes attaining new experiences and skills that go beyond science, technology or engineering. Students learn to present their ideas to an authentic public that may consist of parents, teachers and the top scientists in a given field.

Science fair projects typically consist of:

- an experiment, which is an original scientific experiment with a specific, original hypothesis. Students should control all important variables and demonstrate appropriate data collection and analysis techniques;
- a study, which involves the collection of data to reveal a pattern or correlation. Studies can include cause and effect relationships and theoretical investigations of the data. Studies are often carried out using surveys given to human subjects; or,
- an innovation, which deals with the creation and development of a new device, model, or technique in a technological field. These innovations may have commercial applications or be of benefit to humans.

Youth Science Canada provides further information regarding science fairs and festivals in Canada.

An Effective Science Education Program

An effective science education program supports student achievement of learning outcomes through:

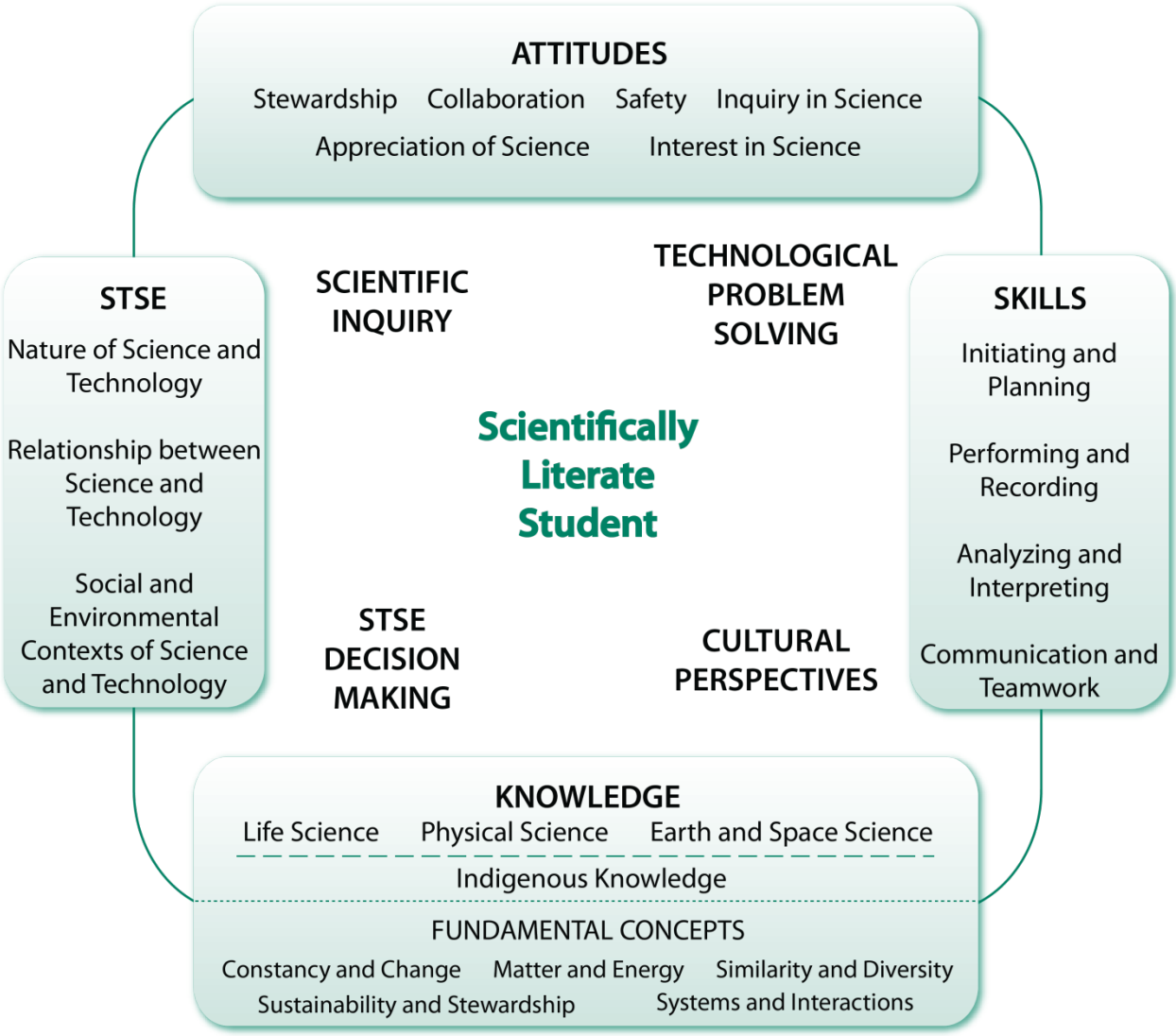
- incorporating all foundations of scientific literacy;
- using the learning contexts as entry points into student inquiry;
- understanding and effectively using the language of science;
- engaging in laboratory and field work;
- practicing safety; and
- choosing and using technology in science appropriately.

All science outcomes and indicators emphasize one or more foundations of scientific literacy; these represent the "what" of the curriculum. The learning contexts represent different processes for engaging students in achieving curricular outcomes; they are the "how" of the curriculum.

Scientists construct models to support their explanations based on empirical evidence. Students need to engage in similar processes through authentic laboratory work. During their investigations, students must follow safe practices in the laboratory, as well as in regard to living things.

Technology serves to extend our powers of observation and to support the sharing of information. Students should use a variety of technology tools for data collection and analysis, for visualization and imaging and for communication and collaboration throughout the science curriculum.

To achieve the vision of scientific literacy outlined in this curriculum, students must increasingly become engaged in the planning, development and evaluation of their own learning activities. In the process, students should have the opportunity to work collaboratively with others, to initiate investigations, to communicate findings and to complete projects that demonstrate learning.



- All science outcomes and indicators emphasize one or more of the foundations of scientific literacy (STSE, Knowledge, Skills and Attitudes); these represent the "what" of the curriculum. All outcomes are mandatory.
- The four learning contexts (Scientific Inquiry, Technological Problem Solving, Cultural Perspectives and STSE Decision Making) represent different processes for engaging students in achieving curricular outcomes; they represent the "how" of the curriculum.

Foundations of Scientific Literacy

The K-12 goals of science education parallel the foundation statements for scientific literacy described in the *Common Framework of Science Learning Outcomes K to 12* (CMEC, 1997). These four foundation statements delineate the critical aspects of students' scientific literacy. They reflect the wholeness and interconnectedness of learning and should be considered interrelated and mutually supportive.

Foundation 1: Science, Technology, Society and the Environment (STSE) Interrelationships

This foundation is concerned with understanding the scope and character of science, its connections to technology and the social and environmental contexts in which it is developed. This foundation is the driving force of scientific literacy. Three major dimensions address this foundation.

Nature of Science and Technology

Science is a social and cultural activity anchored in a particular intellectual tradition. It is one way of knowing nature, based on curiosity, imagination, intuition, exploration, observation, replication, interpretation of evidence and consensus making over this evidence and its interpretation. More than most other ways of knowing nature, science excels at predicting what will happen next, based on its descriptions and explanations of natural and technological phenomena.

Science-based ideas are continually being tested, modified and improved as new ideas supersede existing ones. Technology, like science, is a creative human activity, but is concerned with solving practical problems that arise from human/social needs, particularly the need to adapt to the environment and to fuel a nation's economy. New products and processes are produced by research and development through inquiry and design.

Relationships between Science and Technology

Historically, the development of technology has been strongly linked to the development of science, with each making contributions to the other. While there are important relationships and interdependencies, there are also important differences. Where the focus of science is on the development and verification of knowledge, in technology, the focus is on the development of solutions, involving devices and systems that meet a given need within the constraints of the problem. The test of science knowledge is that it helps us explain, interpret and predict; the test of technology is that it works – it enables us to achieve a given purpose.

Social and Environmental Contexts of Science and Technology

The history of science shows that scientific development takes place within a social context that includes economic, political, social and cultural forces along with personal biases and the need for peer acceptance and recognition. Many examples show that cultural and intellectual traditions have influenced the focus and methodologies of science, and that science, in turn, has influenced the wider world of ideas. Today, societal and environmental needs and issues often drive research agendas. As technological solutions have emerged from previous research, many of the new technologies have given rise to complex social and environmental issues which are increasingly becoming part of the political agenda. The potential of science, technology and Indigenous knowledge to inform and empower decision making by individuals, communities and society is central to scientific literacy in a democratic society.

Foundation 2: Scientific Knowledge

This foundation focuses on the subject matter of science including the theories, models, concepts and principles that are essential to an understanding of the natural and constructed world. For organizational purposes, this foundation is framed using widely accepted science disciplines.

Life Science

Life science deals with the growth and interactions of life forms within their environments in ways that reflect the uniqueness, diversity, genetic continuity and changing nature of these life forms. Life science includes the study of topics such as ecosystems, biological diversity, organisms, cell biology, biochemistry, diseases, genetic engineering and biotechnology.

Physical Science

Physical science, which encompasses chemistry and physics, deals with matter, energy and forces. Matter has structure, and its components interact. Energy links matter to gravitational, electromagnetic and nuclear forces in the universe. The conservation laws of mass and energy, momentum and charge are addressed in physical science.

Earth and Space Science

Earth and space science brings local, global and universal perspectives to student knowledge. Earth, our home planet, exhibits form, structure and patterns of change, as do our surrounding solar system and the physical universe beyond. Earth and space science includes such fields of study as geology, hydrology, meteorology and astronomy.

Sources of Knowledge about Nature

A strong science program recognizes that modern science is not the only form of empirical knowledge about nature and aims to broaden student understanding of traditional and local knowledge systems. The dialogue between scientists and traditional knowledge holders has an extensive history and continues to grow as researchers and practitioners seek to better understand our complex world. The terms "traditional knowledge", "Indigenous knowledge" and "Traditional Ecological Knowledge" are used by practitioners worldwide when referencing local knowledge systems which are embedded within particular worldviews. This curriculum uses the term "Indigenous knowledge" and provides the following definitions to show parallels and distinctions between Indigenous knowledge and scientific knowledge.

Indigenous Knowledge	Scientific Knowledge
"Traditional [Indigenous] knowledge is a cumulative body of knowledge, know-how, practices and representations maintained and developed by peoples with extended histories of interaction with the natural environment. These sophisticated sets of understandings, interpretations and meanings are part and parcel of a cultural complex that encompasses language, naming and classification systems, resource use practices, ritual, spirituality and worldview" (International Council for Science, 2002, p. 3).	Similar to Indigenous knowledge, scientific knowledge is a cumulative body of knowledge, know-how, practices and representations maintained and developed by people (scientists) with extended histories of interaction with the natural environment. These sophisticated sets of understandings, interpretations and meanings are part and parcel of cultural complexes that encompass language, naming and classification systems, resource use practices, ritual and worldview.

Fundamental Concepts – Linking Scientific Disciplines

A useful way to create linkages among science disciplines is through fundamental concepts that underlie and integrate different scientific disciplines. Fundamental concepts provide a context for explaining, organizing and connecting knowledge. Students deepen their understanding of these fundamental concepts and apply their understanding with increasing sophistication as they progress through the curriculum from Kindergarten to Grade 12. These fundamental concepts are identified in the following chart.

Constancy and Change	The ideas of constancy and change underlie understanding of the natural and constructed world. Through observations, students learn that some characteristics of materials and systems remain constant over time whereas other characteristics change. These changes vary in rate, scale and pattern, including trends and cycles, and may be quantified using mathematics, particularly measurement.
Matter and Energy	Objects in the physical world are comprised of matter. Students examine materials to understand their properties and structures. The idea of energy provides a conceptual tool that brings together many understandings about natural phenomena, materials and the process of change. Energy, whether transmitted or transformed, is the driving force of both movement and change.
Similarity and Diversity	The ideas of similarity and diversity provide tools for organizing our experiences with the natural and constructed world. Beginning with informal experiences, students learn to recognize attributes of materials that help to make useful distinctions between one type of material and another, and between one event and another. Over time, students adopt accepted procedures and protocols for describing and classifying objects encountered, thus enabling students to share ideas with others and to reflect on their own experiences.
Systems and Interactions	An important way to understand and interpret the world is to think about the whole in terms of its parts and alternately about its parts in terms of how they relate to one another and to the whole. A system is an organized group of related objects or components that interact with one another so that the overall effect is much greater than that of the individual parts, even when these are considered together.
Sustainability and Stewardship	Sustainability refers to the ability to meet our present needs without compromising the ability of future generations to meet their needs. Stewardship refers to the personal responsibility to take action in order to participate in the responsible management of natural resources. By developing their understanding of ideas related to sustainability, students are able to take increasing responsibility for making choices that reflect those ideas.

Foundation 3: Scientific and Technological Skills and Processes

This foundation identifies the skills and processes students develop in answering questions, solving problems and making decisions. While these skills and processes are not unique to science, they play an important role in the development of scientific and technological understanding and in the application of acquired knowledge to new situations. Four broad skill areas are outlined in this foundation. Each area is developed further at each grade level with increasing scope and complexity of application.

Initiating and Planning

These are the processes of questioning, identifying problems and developing preliminary ideas and plans.

Performing and Recording

These are the skills and processes of carrying out a plan of action, which involves gathering evidence by observation and, in most cases, manipulating materials and equipment. Gathered evidence can be documented and recorded in a variety of formats.

Analyzing and Interpreting

These are the skills and processes of examining information and evidence, organizing and presenting data so that they can be interpreted, interpreting those data, evaluating the evidence and applying the results of that evaluation.

Communication and Teamwork

In science and technology, as in other areas, communication skills are essential whenever ideas are being developed, tested, interpreted, debated and accepted or rejected. Teamwork skills are also important because the development and application of ideas rely on collaborative processes both in science-related occupations and in learning.

Foundation 4: Attitudes

This foundation focuses on encouraging students to develop attitudes, values and ethics that inform a responsible use of science and technology for the mutual benefit of self, society and the environment. This foundation identifies six categories in which science education can contribute to the development of scientific literacy.

Both scientific and Indigenous knowledge systems place value on attitudes, values and ethics. These are more likely to be presented in a holistic manner in Indigenous knowledge systems.

Appreciation of Science

Students will be encouraged to critically and contextually appreciate the role and contributions of science and technology in their lives and to their community's culture; and to be aware of the limits of science and technology as well as their impact on economic, political, environmental, cultural and ethical events.

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Collaboration

Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.

Stewardship

Students will be encouraged to develop responsibility in the application of science and technology in relation to society and the natural environment.

Safety

Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.

Learning Contexts

Learning contexts provide entry points into the curriculum that engage students in inquiry-based learning to achieve scientific literacy. Each learning context reflects a different, but overlapping, philosophical rationale for including science as a required area of study:

- The **scientific inquiry** learning context reflects an emphasis on understanding the natural and constructed world using systematic empirical processes that lead to the formation of theories that explain observed events and that facilitate prediction.
- The **technological problem solving** learning context reflects an emphasis on designing and building to solve practical human problems similar to the way an engineer would.
- The **STSE decision making** learning context reflects the need to engage citizens in thinking about human and world issues through a scientific lens in order to inform and empower decision making by individuals, communities and society.
- The **cultural perspectives** learning context reflects a humanistic perspective that views teaching and learning as cultural transmission and acquisition (Aikenhead, 2006).

Each learning context is identified using a two or three letter code. One or more of these codes are listed under each outcome as a suggestion regarding which learning context or contexts most strongly support the intent of the outcome.

These learning contexts are not mutually exclusive; thus, well-designed instruction may incorporate more than one learning context. Students should experience learning through each learning context at each grade; it is not necessary, nor advisable, for each student to attempt to engage in learning through each learning context in each unit of study. Learning within a classroom may be structured to enable individuals or groups of students to achieve the same curricular outcomes through different learning contexts.

A choice of learning approaches can also be informed by recent well-established ideas on how and why students learn:

- Learning occurs when students are treated as a community of practitioners of scientific literacy.
- Learning is both a social and an individual event for

constructing and refining ideas and competences.

- Learning involves the development of new self-identities for many students.
- Learning is inhibited when students feel a culture clash between their home culture and the culture of school science.

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.

(NRC,1996, p. 23)

Scientific Inquiry [SI]

Inquiry is a defining feature of the scientific way of knowing nature. Scientific inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. Scientific inquiry is a multifaceted activity that involves:

- making observations, including watching or listening to knowledgeable sources;
- posing questions or becoming curious about the questions of others;
- examining books and other sources of information to see what is already known;
- reviewing what is already known in light of experimental evidence and rational arguments;
- planning investigations, including field studies and experiments;
- acquiring the resources (financial or material) to carry out investigations;
- using tools to gather, analyze, and interpret data;
- proposing critical answers, explanations, and predictions; and,
- communicating the results to various audiences.

By participating in a variety of inquiry experiences that vary in the amount of student self-direction, students develop competencies necessary to conduct inquiries of their own – a key element to scientific literacy.

Technological design is a distinctive process with a number of defined characteristics; it is purposeful; it is based on certain requirements; it is systematic; it is iterative; it is creative; and there are many possible solutions.

(International Technology Education Association, 2000, p. 91)

Technological Problem Solving [TPS]

The essence of the technological problem solving learning context is that students seek answers to practical problems. This process is based on addressing human and social needs and is typically addressed through an iterative design-action process that involves steps such as:

- identifying a problem;
- identifying constraints and sources of support;
- identifying alternative possible solutions and selecting one on which to work;
- planning and building a prototype or a plan of action to resolve the problem; and,
- testing, evaluating and refining the prototype or plan.

By participating in a variety of technological and environmental problem-solving activities, students develop capacities to analyze and resolve authentic problems in the natural and constructed world.

STSE Decision Making [DM]

Scientific knowledge can be related to understanding the relationships among science, technology, society and the environment. Students must also consider values or ethics, however, when addressing a question or issue. STSE decision making involves steps such as:

- clarifying an issue;
- evaluating available research and different viewpoints on the issue;
- generating possible courses of action or solutions;
- evaluating the pros and cons for each action or solution;
- identifying a fundamental value associated with each action or solution;
- making a thoughtful decision;
- examining the impact of the decision; and,
- reflecting back on the process of decision making.

Students may engage with STSE issues through research projects, student-designed laboratory investigations, case studies, role playing, debates, deliberative dialogues and action projects.

To engage with science and technology toward practical ends, people must be able to critically assess the information they come across and critically evaluate the trustworthiness of the information source.

(Aikenhead, 2006 p. 2)

Cultural Perspectives [CP]

Students should recognize and respect that all cultures develop knowledge systems to describe and explain nature. Two knowledge systems which are emphasized in this curriculum are First Nations and Métis cultures (Indigenous knowledge) and Euro-Canadian cultures (science). In their own way, both of these knowledge systems convey an understanding of the natural and constructed worlds, and they create or borrow from other cultures' technologies to resolve practical problems. Both knowledge systems are systematic, rational, empirical, dynamically changeable and culturally specific.

Cultural features of science are, in part, conveyed through the other three learning contexts and when addressing the nature of science. Cultural perspectives on science can also be taught in activities that explicitly explore Indigenous knowledge or knowledge from other cultures.

For First Nations people, the purpose of learning is to develop the skills, knowledge, values and wisdom needed to honour and protect the natural world and ensure the long-term sustainability of life.

(Canadian Council on Learning, 2007, p. 18)

For the Métis people, learning is understood as a process of discovering the skills, knowledge and wisdom needed to live in harmony with the Creator and creation, a way of being that is expressed as the Sacred Act of Living a Good Life.

(Canadian Council on Learning, 2007, p. 22)

Addressing cultural perspectives in science involves:

- recognizing and respecting knowledge systems that various cultures have developed to understand the natural world and technologies they have created to solve human problems;
- recognizing that science, as one of those knowledge systems, evolved within Euro-Canadian cultures;
- valuing place-based knowledge to solve practical problems; and,
- honouring protocols for obtaining knowledge from a knowledge keeper, and taking responsibility for knowing it.

By engaging in explorations of cultural perspectives, scientifically literate students begin to appreciate the worldviews and belief systems fundamental to science and to Indigenous knowledge.

The Language of Science

Science is a way of understanding the natural world using internally consistent methods and principles that are well-described and understood by the scientific community. The principles and theories of science have been established through repeated experimentation and observation and have been refereed through peer review before general acceptance by the scientific community. Acceptance of a theory does not imply unchanging belief in a theory, or denote dogma. Instead, as new data become available, previous scientific explanations are revised and improved, or rejected and replaced. There is a progression from a hypothesis to a theory using testable, scientific laws. Many hypotheses are tested to generate a theory. Only a few scientific facts are considered laws (e.g., the law of conservation of mass and Newton's laws of motion).

Scientists use the terms "law", "theory" and "hypothesis" to describe various types of scientific explanations about phenomena in the natural and constructed world. These meanings differ from common usage of the same terms:

The terms "law", "theory" and "hypothesis" have special meaning in science.

- Law – A law is a generalized description, usually expressed in mathematical terms, that describes some aspect of the natural world under certain conditions.
- Theory – A theory is an explanation for a set of related observations or events that may consist of statements, equations, models or a combination of these. Theories also predict the results of future observations. An explanation is verified multiple times by different groups of researchers before it becomes a theory. The procedures and processes for testing a theory are well-defined within each scientific discipline, but they vary between disciplines. No amount of evidence proves that a theory is correct. Rather, scientists accept theories

until the emergence of new evidence that the theory is unable to adequately explain. At this point, the theory is

discarded or modified to explain the new evidence. Note that theories never become laws; theories explain laws.

- Hypothesis – A hypothesis is a tentative, testable generalization that may be used to explain a relatively large number of events in the natural world. It is subject to immediate or eventual testing by experiments. Hypotheses must be worded in such a way that they can be falsified. Hypotheses are never proven correct, but are supported by empirical evidence.

Scientific models are constructed to represent and explain certain aspects of physical phenomenon. Models are never exact replicas of real phenomena; rather, models are simplified versions of reality, constructed in order to facilitate study of complex systems such as the atom, climate change and biogeochemical cycles. Models may be physical, mental, mathematical or contain a combination of these elements. Models are complex constructions that consist of conceptual objects and processes in which the objects participate or interact. Scientists spend considerable time and effort building and testing models to further understanding of the natural world.

When engaging in the processes of science, students are constantly building and testing their own models of understanding of the natural world. Students may need help in learning how to identify and articulate their own models of natural phenomena. Activities that involve reflection and metacognition are particularly useful in this regard. Students should be able to identify the features of the natural phenomena their models represent or explain. Just as importantly, students should identify which features are not represented or explained by their models. Students should determine the usefulness of their model by judging whether the model helps in understanding the underlying concepts or processes. Ultimately, students realize that different models of the same phenomena may be needed in order to investigate or understand different aspects of the phenomena.

Laboratory Work

Laboratory work is often at the centre of scientific research; as such, it should also be an integral component of school science. The National Research Council (2006, p. 3) defines a school laboratory investigation as an experience in the laboratory, the classroom or the field that provides students with opportunities to interact directly with natural phenomena or with data collected by others using tools, materials, data collection techniques and models. Laboratory experiences should be designed so that all students – including students with academic and physical challenges – are able to authentically participate in and benefit from those experiences.

Ideally, laboratory work should help students to understand the relationship between evidence and theory, develop critical thinking and problem- solving skills, as well as develop acceptable scientific attitudes.

(Di Giuseppe, 2007, p. 54)

Laboratory activities help students develop scientific and technological skills and processes including:

- initiating and planning;
- performing and recording;
- analyzing and interpreting; and,
- communication and teamwork.

Laboratory investigations also help students understand the nature of science; specifically that theories and laws must be consistent with observations. Similarly, student-centered laboratory investigations help to emphasize the need for curiosity and inquisitiveness as part of the scientific endeavour. The National Science Teachers Association (NSTA) position statement *The Integral Role of Laboratory Investigations in Science Instruction* (2007) provides further information about laboratory investigations.

A strong science program includes a variety of individual, small- and large-group laboratory experiences for students. Most importantly, the laboratory experience needs to go beyond conducting confirmatory "cook-book" experiments. Similarly, computer simulations and teacher demonstrations are valuable but should not serve as substitutions for hands-on student laboratory activities.

Assessment and evaluation of student performance must reflect the nature of the laboratory experience by addressing scientific and technological skills. As such, the results of student investigations and experiments do not always need to be presented using formal laboratory reports. Teachers may consider alternative formats such as narrative lab reports for some investigations. The narrative lab report enables students to tell the story of their process and findings by addressing four questions:

- What was I looking for?
- How did I look for it?
- What did I find?
- What do these findings mean?

Student responses to these questions may be provided orally, in point form or through other methods rather than using the structured headings of Purpose, Procedure, Hypothesis, Data, Analysis and Conclusion typically associated with a formal laboratory report. For some investigations, teachers may decide it is sufficient for students to explain the significance of their findings.

Safety

Safety in the classroom is of paramount importance. Other components of education (e.g., resources, teaching strategies and facilities) attain their maximum utility only in a safe classroom. To create a safe classroom requires that a teacher be informed, aware and proactive and that the students listen, think and respond appropriately.

Safety cannot be mandated solely by rule of law, teacher command, or school regulation. Safety and safe practice are an attitude.

Safe practice in the laboratory is the joint responsibility of the teacher and students. The teacher's responsibility is to provide a safe environment and to ensure the students are aware of safe practice. The students' responsibility is to act intelligently based on the advice which is given and which is available in various resources.

Teachers should be aware of *Safety in the K-12 Science Classroom* (Worksafe Saskatchewan, 2013). This resource supports planning and safe learning by providing information on safety legislation and standards. It provides examples of common chemical, physical and biological hazards and shows how to protect against, minimize and eliminate these hazards.

The Chemical Hazard Information Table in Safety in the K-12 Science Classroom (Worksafe Saskatchewan, 2013) provides detailed information including appropriateness for school use, hazard ratings, WHMIS class, storage class and disposal methods for hundreds of chemicals.

Texley, Kwan, and Summers (2004) suggest that teachers, as professionals, consider four Ps of safety: prepare, plan, prevent and protect. The following points are adapted from those guidelines and provide a starting point for thinking about safety in the science classroom:

- **Prepare**
  - Keep up to date with your personal safety knowledge and certifications.
  - Be aware of national, provincial, school division and school level safety policies and guidelines.
  - Create a safety contract with students.
- **Plan**
  - Develop learning plans that ensure all students learn effectively and safely.
  - Choose activities that are best suited to the learning styles, maturity and behaviour of all students and that include all students.
  - Create safety checklists for in-class activities and field studies.
- **Prevent**
  - Assess and mitigate hazards.
  - Review procedures for accident prevention with students.
  - Teach and review safety procedures with students, including the need for appropriate clothing.
  - Do not use defective or unsafe equipment or procedures.

- Do not allow students to eat or drink in science areas.

- **Protect**
  - Ensure students have sufficient protective devices, such as safety glasses.
  - Demonstrate and instruct students on the proper use of safety equipment and protective gear.
  - Model safe practice by insisting that all students, visitors and you use appropriate protective devices.

The definition of safety includes consideration of the well-being of all components of the biosphere, such as plants, animals, earth, air and water. From knowing what wild flowers can be picked to considering the disposal of toxic wastes from chemistry laboratories, the safety of our world and our future depends on our actions and teaching in science classes. It is important that students practise ethical, responsible behaviours when caring for and experimenting with live animals. For further information, refer to the NSTA position statement *Responsible Use of Live Animals and Dissection in the Science Classroom* (2008).

WHMIS regulations govern storage and handling practices of chemicals in schools.

Safety in the science classroom includes the storage, use and disposal of chemicals. The *Workplace Hazardous Materials Information System* (WHMIS) regulations (WHMIS 2015) under the *Hazardous Products Act* and the *Hazardous Product Regulations* govern storage and handling practices of chemicals in schools. All school divisions must comply with the provisions of these regulations. Chemicals should be stored in a safe location according to chemical class, not just alphabetically. Appropriate cautionary labels must be placed on all chemical containers and all school division employees using hazardous substances should have access to appropriate *Safety Data Sheets* (SDSs). Under provincial WHMIS regulations, all employees involved in handling hazardous substances must receive training by their employer. Teachers who have not been informed about or trained in this program should contact their director of education. Further information related to WHMIS is available through WorkSafe Saskatchewan.

Technology in Science

Technology-based resources are essential for instruction in the science classroom. Technology is intended to extend our capabilities and, therefore, is one part of the teaching toolkit. Individual, small group or class reflection and discussions are required to connect the work with technology to the conceptual development, understandings and activities of the students. Choices to use technology, and choices of which technologies to use, should be based on sound pedagogical practices, especially those which support student inquiry. These technologies include computer technologies as described below and non-computer based technologies.

Some recommended examples of using computer technologies to support teaching and learning in science include:

- **Data Collection and Analysis**
  - Data loggers permit students to collect and analyze data, often in real-time, and to collect observations over very short or long periods of time, enabling investigations that otherwise would be impractical.
  - Databases and spreadsheets can facilitate the analysis and display of student-collected data or data obtained from scientists.
- **Visualization and Imaging**
  - Simulation and modeling software provide opportunities to explore concepts and models which are not readily accessible in the classroom, such as those that require expensive or unavailable materials or equipment, hazardous materials or procedures, levels of skills not yet achieved by the students or more time than is possible or appropriate in a classroom.
  - Students may collect their own digital images and video recordings as part of their data collection and analysis or they may access digital images and video online to help enhance understanding of scientific concepts.
- **Communication and Collaboration**
  - The Internet can be a means of networking with scientists, teachers, and other students by gathering information and data, posting data and findings, and comparing results with students in different locations.
  - Students can participate in authentic science projects by contributing local data to large-scale web-based science inquiry projects such as Journey North or GLOBE.

Technology should be used to support learning in science when it:

- *is pedagogically appropriate;*
- *makes scientific views more accessible; and,*
- *helps students to engage in learning that otherwise would not be possible.*

(Flick & Bell, 2000)

Outcomes at a Glance

Career Exploration
PS20-CE1 Analyze and explore physical science related occupations in Saskatchewan, Canada and the world.

Student-Directed Study
PS20-SDS1 Create and carry out a plan to explore one or more topics of personal interest relevant to *Physical Science 20* in depth.

Heat
PS20-HT1 Analyze, qualitatively and quantitatively, the effect of heat on matter during temperature changes and changes of state using kinetic molecular theory.
PS20-HT2 Determine the quantities of heat involved in chemical reactions through experimentation and calculation.

Foundations of Chemistry
PS20-FC1 Predict products of the five basic types of chemical reactions and evaluate the impact of these reactions on society and the environment.
PS20-FC2 Construct an understanding of the mole as a unit for measuring the amount of substance.
PS20-FC3 Use stoichiometry to determine the relative amounts of substances consumed and produced in chemical reactions.

Properties of Waves
PS20-PW1 Investigate the properties and characteristics of one-, two- and three-dimensional waves in at least three different media (e.g., springs, ropes, air and water).
PS20-PW2 Examine, using physical materials, ray diagrams and mathematical equations, how waves reflect from a variety of barriers.
PS20-PW3 Analyze, using physical materials, ray diagrams and mathematical equations, how waves refract at boundaries between different media.

Legend

PS20-FC1a	
PS20	Course name
FC	Unit of study
1	Outcome number
a	Indicator
[CP, DM, SI, TPS]	Learning context(s) that best support this outcome
(A, K, S, STSE)	Foundation(s) of Scientific Literacy that apply to this indicator

Outcomes and Indicators

Career Exploration	
All outcomes contribute to the development of all K-12 science goals.	
Outcomes	**Indicators**
PS20-CE1 Analyze and explore physical science related occupations in Saskatchewan, Canada and the world. [CP, DM]	a. Generate a list of occupations that require a background in physical science through research and/or participation in events such as a career fair or job shadow. (K, S) b. Explore connection between topics in *Physical Science 20* and occupations of personal interest. (S, A, STSE) c. Identify which physical science related occupations are facing shortages and which are oversubscribed locally, regionally and/or nationally. (STSE, S, K, A) d. Examine the roles, responsibilities, educational qualifications and personal and professional qualities common to people involved in physical-science related jobs. (S, A) e. Reflect upon personal suitability or non-suitability for a specific physical-science related occupation considering criteria such as: • initial and continuing educational requirements; • duties and skills required for this occupation; • the work environment, including typical hours and shifts worked and typical locations; • current wages received in Saskatchewan and how these compare to the rest of Canada; • physical, mental and emotional stresses related to this occupation; • workplace hazards and safety considerations; • other occupations with which they interact; • professional and/or licensing requirements in Canada and Saskatchewan; and • future trends impacting the occupation. (K, S, A, STSE) f. Interview or connect with others to discuss physical science related occupations. (K, S, A) g. Communicate research findings related to physical science occupations through a display, brochure, video, presentation software, website or orally. (K, S, A, STSE) h. Develop a plan to attain your dream job in the physical science field. (S, A)

Student-Directed Study	
All outcomes contribute to the development of all K-12 science goals.	
Outcomes	**Indicators**
PS20-SDS1 Create and carry out a plan to explore one or more topics of personal interest relevant to *Physical Science 20* in depth. [DM, SI, TPS]	a. Design a scientific investigation related to a topic of study in *Physical Science 20* that includes a testable question, a hypothesis, an experimental design that will test the hypothesis and detailed procedures for collecting and analyzing data. (STSE, S). b. Carry out an experiment following established scientific protocols to investigate a question of interest related to one or more of the topics of *Physical Science 20*. (S, A, K, STSE) c. Assemble and reflect on a portfolio that demonstrates an understanding of a physical science topic of interest to the student. (S, A) d. Design, construct and evaluate the effectiveness of a device, model or technique that demonstrates the scientific principles underlying a concept related to *Physical Science 20*. (STSE, S) e. Debate an issued related to physical science, including developing materials to support the arguments for and against a position. (A, K, S) f. Share the results of student-directed research through a display, presentation, performance, demonstration, song, game, commercial, fine art representation, video or research paper. (S) g. Construct a tool (e.g., rubric, checklist, self-evaluation form or peer-evaluation form) to assess the process and products involved in a student-directed study. (S, A)

Heat	
All outcomes contribute to the development of all K-12 science goals.	
Outcomes	**Indicators**
PS20-HT1 Analyze, qualitatively and quantitatively, the effect of heat on matter during temperature changes and changes of state using kinetic molecular theory. [CP, DM, SI]	a. Distinguish between heat and temperature using the kinetic molecular theory of matter. (K) b. Explore the importance of heat and fire for First Nations and Métis peoples, and how they use their understanding of heat transfer to solve practical problems related to cooking and shelter. (STSE, K, A) c. Discuss how the concept of a closed system and the law of conservation of energy underlie the study of heat and heat transfer. (STSE) d. Measure the specific heat capacity of various metals using a calorimeter. (S, K) e. Determine the latent heat of fusion and/or latent heat of vaporization of various substances using a calorimeter. (S, K)

	f. Measure some physical properties of water, such as density at various temperatures, specific heat capacity and latent heat of fusion and latent heat of vaporization. (S, K) g. Compare, in quantitative terms, the heat capacities of some common materials, including water, and explain how heat capacity can influence choices of materials used in the development of technologies related to clothing, food and shelter. (STSE, S, K) h. Construct a heating or cooling curve for water, or other substances, using personally collected data and appropriate graphing techniques or software. (S, K) i. Use appropriate technologies such as temperature probes and calorimeters safely when collecting data. (S, A) j. Calculate the quantity of heat ($Q = mc\Delta T$), specific heat capacity, latent heat of fusion ($Q = mH_f$) and latent heat of vaporization ($Q = mH_v$) during changes of state, using the correct number of significant figures. (S, K) k. Calculate and experimentally verify the amount of heat exchanged and final temperature reached when mixing two known quantities of known substances, and suggest sources of experimental error and improvements to experimental design. (S, K, STSE, A) l. Examine traditional and contemporary applications of heat transfer such as heating a drum skin, using heat to make copper tools, energy control in buildings, heat pumps and insulated and moisture wicking clothing. (STSE, S, K) m. Explore, qualitatively and/or quantitatively, the expansion and contraction of matter during heat transfer or temperature change. (S, K) n. Investigate effects of the thermal expansion and contraction of matter in technological applications such as road, bridge and building design, plumbing, power line construction and industrial engineering. (STSE, A) o. Discuss how the anomalous properties (e.g., density, phase and thermodynamic properties) of water, as compared with other liquids, affect the environment and Earth's climate. (STSE, K)
PS20-HT2 Determine the quantities of heat involved in chemical reactions through experimentation and calculation. [SI, TPS]	a. Distinguish between endothermic and exothermic chemical reactions, including those that occur in solutions. (K) b. Research the historical development of thermodynamics, including significant discoveries and inventions, and the contributions of engineers and scientists such as Carnot, Maxwell, Boltzmann, Lord Kelvin and Gibbs. (STSE) c. Measure, using a thermometer or temperature probe, and record the temperature change in an exothermic and/or endothermic chemical reaction. (S, K) d. Calculate the theoretical quantity of heat absorbed or released in specific exothermic and/or endothermic reactions, including combustion reactions, using various quantities of reactants given the heat of reaction. (S, K)

	e. Explain why the actual heat of reaction differs from the theoretical heat of reaction, with reference to sources of error and percent error calculations. (S, K) f. Discuss the importance of analyzing the quantities of heat involved in chemical reactions. (STSE) g. Calculate the molar heat of reaction associated with dissolving ionic compounds in a solution. (S, K) h. Compare the quantity of heat involved in the use of various commercially available cold and/or heat packs. (STSE, S, K) i. Design, create and evaluate the effectiveness of a cold pack and/or heat pack given the goal of having no excess reactants remaining at reaction completion. (STSE, S, K) j. Compare the fuel consumed and heat energy output of various combustion reactions involving common fuels (e.g., methane, propane, octane and ethanol). (STSE, S)

Foundations of Chemistry	
All outcomes contribute to the development of all K-12 science goals.	
Outcomes	**Indicators**
PS20-FC1 Predict products of the five basic types of chemical reactions and evaluate the impact of these reactions on society and the environment. [DM, SI]	a. Observe and analyze synthesis, decomposition, combustion, single-replacement and double-replacement (including acid base neutralization) reactions. (S, K) b. Represent synthesis, decomposition, combustion, single-replacement and double-replacement (including acid base neutralization) reactions using atomic models, other manipulatives, skeleton equations, balanced chemical equations and International Union of Pure and Applied Chemistry (IUPAC) nomenclature. (S) c. Explain the importance of skeleton equations, balanced equations and IUPAC nomenclature in communicating understanding of chemical reactions. (S, K, A) d. Predict products of synthesis and decomposition reactions given the reactants. (S, K) e. Determine the feasibility of single-replacement reactions based on the activity series of metals and/or non-metals. (S, K) f. Predict products of double-replacement reactions, including acid-base neutralization reactions, and precipitate formation using solubility rules. (S, K) g. Distinguish between the products of complete and incomplete combustion reactions and potential consequences of the latter for living things and the environment. (STSE, K) h. Design, and carry out if practical, an investigation to demonstrate the difference between a complete and incomplete combustion reaction. (S) i. Select and apply proper techniques for handling and disposing of lab materials, as outlined in *Workplace Hazardous Materials*

	Information System (WHMIS 2015) standards, and interpret *Safety Data Sheets* (SDSs). (K, STSE, A) j. Analyze and compare the fuel consumed and carbon output of various combustion reactions (e.g., methane, propane, octane and ethanol). (STSE, S) k. Describe how the outcomes of various chemical reactions may benefit or harm living organisms and affect the environment. (K, STSE) l. Research how industrial, mining and/or agricultural processes involve chemical reactions. (STSE, S, K, A)
PS20-FC2 Construct an understanding of the mole as a unit for measuring the amount of substance. [DM, SI]	a. Pose questions about how to measure quantities of substances that are not readily countable. [S] b. Relate counting by weighing to the sale of a granular product such as grain or gravel, the purchase of bulk foods, rolled coin deposits at the bank and purchasing propane for a barbeque. (K) c. Provide examples to demonstrate the size of the Avogadro constant (6.02×10^{23}) in relation to common items such as coins, water drops, sand grains and marbles. (K) d. Explain why chemists use the mole to represent the amount of a substance. (K, STSE) e. Outline how individuals such as Avogadro, Berzelius, Davy, Gay-Lussac, Proust and Dalton have contributed to modern understanding of the composition of compounds. (STSE, A) f. Celebrate mole day on 10/23 or 6/02 by bringing a multiple of a mole of substance to school, consuming a mole of a substance and creating and/or sharing cartoons, articles, pictures or songs relevant to the mole. (A) g. Calculate the molar mass of various molecular and ionic compounds. (S) h. Perform molar conversions, including mass to mole, number of particles to mole, volume to mole, concentration of a solution to mole and their inverse operations, using the correct number of significant figures. (S) i. Prepare solutions of known concentration using molarity and dilution calculations. (S, K) j. Research the use of solutions in industrial, mining and agricultural processes. (STSE, S, K)
PS20-FC3 Use stoichiometry to determine the relative amounts of substances consumed and produced in chemical reactions. [SI]	a. Pose questions about how to determine the amount of material required to produce a finished product. (S) b. Determine the relative numbers of moles of each substance in a variety of chemical reactions using balanced chemical equations. (K, S) c. Relate the use of the mole to the coefficients in a balanced chemical equation, and compare this to mass and volume as measurable quantities. (K, A, STSE) d. Perform stoichiometric calculations to predict the outcomes (e.g., concentration, mass, volume, number of particles and energy transferred) of chemical reactions, using the correct

	units and correct number of significant figures. (S) e. Design and carry out experiments to support stoichiometric hypotheses using appropriate instruments to collect data accurately and precisely. (S, A) f. Communicate results of experiments using narrative and formal lab reports. (S, A) g. Determine the limiting and excess reagents in a variety of chemical reactions through stoichiometric calculations and experimentation. (S, K) h. Compare the theoretical and actual yield for a variety of chemical reactions by calculating the percent yield. (S, K) i. Explain how actual yield differs from theoretical yield using the concept of sources of error. (STSE, S) j. Predict how to maximize the yield of a particular chemical process. (STSE, S) k. Discuss the economic impact of the yield of chemical reactions with respect to maximizing product and profit and minimizing waste production. (STSE, A) l. Research how the reactants used and products formed through chemical reactions in industrial, mining and/or agricultural processes can affect human health and/or the health of the environment. (STSE, A)

Properties of Waves	
All outcomes contribute to the development of all K-12 science goals.	
Outcomes	**Indicators**
PS20-PW1 Investigate the properties and characteristics of one-, two- and three-dimensional waves in at least three different media (e.g., springs, ropes, air and water). [SI]	a. Pose questions about the nature and prevalence of waves in the world around us (e.g., What are waves? Where do we find waves in the world around us? Do all waves exhibit the same properties and behaviours? Why are waves important to study?). (S, STSE, A) b. Examine First Nations and Metis perspectives on waves, including waves as carriers of energy. (STSE, K) c. Recognize that scientists understand waves as the transmission of energy originating from a vibrating source that determines the frequency and amplitude of the wave. (K) d. Communicate information about the properties and characteristics of waves using appropriate terminology, including medium, pulse, vibration, cycle, periodic motion, frequency, period, amplitude, phase and wavelength. (S, K) e. Rephrase questions about waves (e.g., What controls the frequency of a wave? What controls the speed of a wave? What happens when two or more waves meet?) into experimentally testable formats. (S, A) f. Identify characteristics of transverse and longitudinal waves including crests (positive pulse), troughs (negative pulse), compressions, rarefactions and the relationship between

	direction of vibration and energy transfer. (K) g. Describe the characteristics of the transmission of waves, including rectilinear propagation and the nature of the medium and its relationship to the speed of the wave. (S, K) h. Trace the historical developments of technologies used to measure the speed of light and/or sound. (STSE) i. Solve problems related to speed, period, frequency and wavelength using the universal wave equation ($v = \lambda f$), the period-frequency relationship (T = 1/f) and the correct number of significant figures. (S, K) j. Illustrate constructive and destructive interference in one-, two- and three- dimensional waves, including the principle of superposition and standing waves, using point-source and straight-source waves. (S, K) k. Observe and describe diffraction of waves through single and double slits and diffraction gratings. (S, K) l. Provide examples of applications of the properties and characteristics of waves or electromagnetic radiation in various technologies (e.g., ultrasound, sonar, Doppler Effect, sonic booms, satellite dishes, microwaves, mobile phones, wireless routers, Bluetooth, radio waves, X-rays, radar and remote controls). (STSE, K) m. Explore wave-related phenomena such as natural vibrations, forced vibrations, resonance and harmonics in the context of musical instruments and human hearing. (STSE, S, K) n. Examine data or experimental results that provide evidence for the scientific theory of wave-particle duality of light. (STSE, S)
PS20-PW2 Examine, using physical materials, ray diagrams and mathematical equations, how waves reflect from a variety of barriers. [DM, SI]	a. Investigate the behavior of waves as they strike parallel, oblique, and curved barriers. (S, K) b. Compare the characteristics of specular (regular) and diffuse reflection of waves. (S, K) c. Demonstrate the application of the law of reflection when a wave strikes a straight barrier and when a wave encounters the boundary between two different media. (S, K) d. Provide examples of wave and particle reflection in everyday situations such as echoes, reverberation, room acoustics, radar, sonar, parabolic microphones, ultrasound, water waves, satellite dishes, billiard balls and ball-based sports. (STSE, K, A) e. Investigate image formation in plane, concave and convex mirrors, including constructing ray diagrams. (S, K) f. Identify the properties, including type (real or virtual), attitude/orientation (upright or inverted), magnification (smaller, larger or same size) and position (relative to the mirror surface or vertex), of images formed in plane, concave and convex mirrors. (K) g. Apply the laws of reflection, the magnification equation ($M = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$) and the curved mirror equation ($\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$) to solve problems related to the reflection of waves. (S, K)

	h. Describe the implications of wave-based technologies in furthering scientific understanding of phenomena such as Earth's internal structure, the topography of the ocean floor and the rock cycle. (STSE, K)
PS20-PW3 Analyze, using physical materials, ray diagrams and mathematical equations, how waves refract at boundaries between different media. [DM, SI]	a. Pose scientific questions about how waves behave when they travel from one medium to another. (S) b. Examine the behavior of waves, including partial reflection and refraction, the critical angle and total internal reflection, at a boundary between different media. (S, K) c. Relate refraction, and the refractive index of a medium, to the change in the speed and direction of waves at a boundary between different media. (S, K) d. Investigate image formation in converging and diverging lenses, including constructing ray diagrams. (S, K) e. Identify the properties, including type (real or virtual), attitude/orientation (upright or inverted), magnification (smaller, larger, or same size) and position (relative to the optical center) of images formed in converging and diverging lenses. (K) f. Apply Snell's Law ($n_1 \sin\theta_1 = n_2 \sin\theta_2$), the magnification equation ($M = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$) and the lens equation ($\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$) to solve problems related to the refraction of waves. (S, K) g. Explore applications related to fiber optics, lenses and human vision including polarization, the lens makers equation and total internal reflection. (STSE, S, K)

Assessment and Evaluation of Student Learning

Assessment and evaluation require thoughtful planning and implementation to support the learning process and to inform teaching. All assessment and evaluation of student achievement must be based on the outcomes in the provincial curriculum.

Assessment involves the systematic collection of information about student learning with respect to:

- achievement of provincial curriculum outcomes;
- effectiveness of teaching strategies employed; and,
- student self-reflection on learning.

Evaluation compares assessment information against criteria based on curriculum outcomes for the purpose of communicating to students, teachers, parents/caregivers and others about student progress and to make informed decisions about the teaching and learning process.

There are three interrelated purposes of assessment. Each type of assessment, systematically implemented, contributes to an overall picture of an individual student's achievement.

Assessment for learning involves the use of information about student progress to support and improve student learning, inform instructional practices, and:

- is teacher-driven for student, teacher and parent use;
- occurs throughout the teaching and learning process, using a variety of tools; and,
- engages teachers in providing differentiated instruction, feedback to students to enhance their learning and information to parents in support of learning.

Assessment as learning actively involves student reflection on learning, monitoring of her/his own progress, and:

- supports students in critically analyzing learning related to curricular outcomes;
- is student-driven with teacher guidance; and,
- occurs throughout the learning process.

Assessment of learning involves teachers' use of evidence of student learning to make judgements about student achievement and:

- provides opportunity to report evidence of achievement related to curricular outcomes;
- occurs at the end of a learning cycle, using a variety of tools; and,
- provides the foundation for discussions on placement or promotion.

Glossary

Acids are substances that produce hydrogen ions [H^+] when dissolved in water; they are sour-tasting, good conductors of electricity, turn blue litmus paper red and react with bases to form salts and water.

An **activity series** is a list of chemical elements in order of decreasing reactivity.

The **actual yield** is the amount of product produced as a result of a chemical reaction.

Anomalous means different than what is normal or expected.

Amplitude is the maximum displacement an object moves from equilibrium in an oscillation, and the maximum distance from the rest position to the top of a crest or bottom of a trough.

The **Avogadro constant**, 6.02×10^{23}, is the number of representative particles in a mole of a substance.

A **balanced chemical equation** has the same number of atoms of each element on each side of the equation.

Bases are substances that produced hydroxide ions [OH^-] when dissolved in water; they are bitter tasting, good conductors of electricity, feel slippery, turn red litmus paper blue and react with acids to form salts and water.

A **calorimeter** is an insulated device that is used to measure the amount of heat released or absorbed during a physical or chemical process.

A **chemical reaction** is a process that involves the formation of new substances with new properties.

A **closed system** is a system that does not gain or lose mass.

A **coefficient** is a small whole number that appears in front of a formula in a balanced chemical equation.

A **combustion reaction** is a chemical reaction in which an element or compound reacts with oxygen, releasing energy in the form of heat and light.

A **compression** is the point on a medium where a longitudinal wave has the maximum density.

A **concave mirror** has an inwardly curving reflective surface as seen by the observer and reflects parallel light rays towards a common focal point in front of the mirror.

Concentration is a measurement of the amount of solute that is dissolved in a given quantity of solvent; it is usually expressed in moles/Litre (mol/L).

Constructive interference occurs when two interfering waves in a medium have a displacement in the same direction.

A **converging lens** is thicker at its centre than its edges and refracts parallel rays of light towards a common focal point.

A **convex mirror** has an outwardly curving reflective surface as seen by the observer and reflects parallel light rays away from a common focal point that appears to be behind the mirror.

The **crest** of a wave is the point on the medium that exhibits the maximum positive or upward displacement from the rest position.

The **critical angle** is the angle of incidence that produces an angle of refraction of 90° for any two media.

Cultural perspectives is the learning context that reflects a humanistic perspective which views teaching and learning as cultural transmission and acquisition.

A **cycle** is one complete back and forth motion or oscillation.

A **decomposition reaction** is a chemical reaction in which a single compound is broken down into two or more simpler products.

Destructive interference occurs when two interfering waves in a medium have a displacement in the opposite direction.

Diffraction is the change in direction of waves as they pass through an opening or around a barrier.

A **diffraction grating** is a device, commonly a sheet of glass or plastic etched with a large number of parallel lines, which diffracts light and forms a diffraction pattern of overlapping single-slit interference diffraction patterns.

Diffuse reflection is the scattered, fuzzy reflection produced by reflection of light off of a rough surface.

Dilution refers to reducing the concentration of a chemical.

A **diverging lens** is thinner at its centre than its edges and refracts parallel rays of light away from a common focal point.

A **double-replacement reaction** is a chemical reaction that involves an exchange of positive ions between two compounds.

An **endothermic** reaction absorbs energy from the surroundings.

An **excess reagent** is a reagent present in a quantity that is more than sufficient to react with a limiting reagent, or any reactant that remains after the limiting reagent is used up in a chemical reaction.

An **exothermic** reaction releases energy to the surroundings.

Frequency refers to how often the particles of a medium vibrate when a wave passes through the medium; it is represented by the symbol f and measured in Hertz (Hz).

Harmonics are whole number multiples of a fundamental frequency.

Heat is the transfer of thermal energy, which occurs spontaneously from a warmer object to a cooler object; it is represented by the symbol Q and measured in Joules (J).

The **heat of reaction** is a measure of the change in enthalpy for a chemical reaction.

An **ionic compound** is a neutral compound that consists of positive and negative ions held together by an ionic bond.

The **kinetic molecular theory of matter** describes the behaviour of matter in terms of particles in motion.

Latent heat of fusion is the amount of thermal energy required to change 1 kg of a substance from a solid state to a liquid state at its melting point; it is measured in Joules/kilogram (J/kg).

Latent heat of vaporization is the amount of thermal energy required to change 1 kg of a substance from a liquid state to a gaseous state at its boiling point; it is measured in Joules/kilogram (J/kg).

The **law of conservation of energy** is a physical law that that states that the total energy of a closed system remains constant.

The **law of reflection** states that the angle of incidence is equal to the angle of reflection and in the same plane when a ray reflects off of a flat surface.

A **limiting reagent** is any reactant that is used up first in a chemical reaction and that determines the amount of product that can be formed in the reaction.

In a **longitudinal wave**, the motion of the medium is parallel to the motion of the wave.

The **medium** is the substance through which a wave travels.

Molar heat of reaction is the amount of energy absorbed when one mole of reactants reacts; it is measured in Joules (J).

Molarity is the concentration of solute in a solution expressed as the number of moles of solute dissolved in 1 L of solution; it is measured in moles/Litre (mol/L).

Molar mass is a measure of the mass of a mole of a given substance; it is measured in grams (g).

A **mole** is the SI unit for amount of substance, represented by the symbol mol, and is defined as the amount of chemical substance that contains 6.02×10^{23} representative particles of that substance.

A **molecular compound** is a neutral compound composed of two or more non-metallic elements held together by covalent bonds.

Neutralization is the reaction between an acid and a base in an aqueous solution to produce a salt and water.

Nomenclature is a system of names or terms; in chemistry this is the system for naming chemical compounds.

Percent error is the percent that a measured value differs from the accepted value.

The **period** of a wave is the amount of time required for one complete cycle of an oscillation of a wave; it is represented by the symbol T and measured in seconds (s).

Periodic motion is any motion that repeats in a regular cycle.

A **plane mirror** is a smooth, flat reflecting surface.

A **precipitate** is a solid that forms and settles out of a liquid mixture.

The **principle of superposition** states that the resulting amplitude of two interfering waves is equal to the sum of the individual amplitudes.

A **pulse** is a disturbance of short duration in a medium.

A **rarefaction** is the point on a medium where a longitudinal wave has the minimum density.

A **ray diagram** is a diagram showing the result of a light ray interacting with a surface.

A **real image** is formed when the outgoing rays from a point converge at a real location and thus can be projected onto a screen.

Rectilinear propagation is the movement of light in straight lines through a uniform medium.

Reflection is the change in direction of a wave at an interface between two different media.

Refraction is the change in direction of waves as they pass from one medium to another of different refractive index.

The **refractive index** of a medium is the ratio of the speed of light in a vacuum to the speed of light in the medium; it is denoted by the symbol n.

Resonance is the increase in amplitude of a wave due to transfer of energy that is in phase with the natural frequency of the wave.

Scientific inquiry is the learning context that reflects an emphasis on understanding the natural and constructed world using systematic empirical processes that lead to the formation of theories that explain observed events and that facilitate prediction.

Scientific literacy is an evolving combination of the knowledge of nature, skills, processes and attitudes students need to develop inquiry, problem-solving and decision-making abilities to become lifelong learners and to maintain a sense of wonder about and responsibility towards the natural and constructed world.

A single replacement reaction is a chemical reaction in which one element replaces a second element in a compound; also called a displacement reaction.

Solubility is the amount of a substance that dissolves in a given quantity of solvent at specified conditions of temperature and pressure to produce a saturated solution.

A **solution**, also called a homogeneous mixture, is a uniform mixture that can contain solids, liquids or gases.

Specific heat capacity is the amount of heat required to raise the temperature of one gram of a substance by one degree Celsius; it is represented by the symbol c and measured in Joules/gram•degree Celsius (J/g·°C).

Specular reflection is reflection of light off of a smooth surface in which parallel light rays are reflected in parallel.

A **standing wave** is a wave that remains in a constant position.

Stoichiometry, which is based on the law of conservation of mass, is the calculation of relative quantities of reactants and products in chemical reactions.

STSE decision making is the learning context that reflects the need to engage citizens in thinking about human and world issues through a scientific lens in order to inform and empower decision making by individuals, communities and society.

STSE, which stands for science, technology, society and the environment, is the foundation of scientific literacy that is concerned with understanding the scope and character of science, its connections to technology and the social context in which it is developed.

A **synthesis reaction** is a chemical reaction in which two or more substances react to form a single new substance; also called a combination reaction.

A **system** is two or more objects that interact with each other.

Technological problem solving is the learning context that reflects an emphasis on designing and building to solve practical human problems.

Temperature is a measure of the average kinetic energy of particles in matter; it is measured in degrees Celsius (°C).

Theoretical yield is the maximum amount of product that could form during a chemical reaction from a given amount of reactant.

Thermodynamics is the study of heat changes that accompany chemical reactions and phase changes.

Total internal reflection is the reflection of all incident light back into an optically denser medium when the angle of incidence is greater than the critical angle.

In a **transverse wave**, the motion of the medium is perpendicular to the motion of the wave.

The **trough** of a wave is the point on the medium that exhibits the maximum negative or downward displacement from the rest position.

A **virtual image** is an image formed when the outgoing rays appear to come from a point behind the object and cannot be projected onto a screen.

The **wavelength** of a wave is the length of one complete wave cycle.

Wave-particle duality is the fact that light exhibits both wave-like and particle-like properties.

A **wave** is a disturbance that moves outward from its source, transferring energy through a medium by means of vibrations.

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1. Please indicate your role in the learning community

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What was your purpose for looking at or using this curriculum?

2. How does this curriculum address the needs of your learning community organization?

Please explain.

The curriculum content is:	Strongly Agree	Agree	Disagree	Strongly Disagree
appropriate for its intended purpose	1	2	3	4
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3. Explain which aspects you found to be :

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