2016 Saskatchewan Curriculum

Chemistry

30

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Government of Saskatchewan
Ministry of Education

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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 *Chemistry 30*.

This curriculum provides the intended learning outcomes that *Chemistry 30* 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).

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

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

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;
- *Chemistry 30* outcomes and indicators;
- sample assessment and evaluation criteria related to outcomes in science; and
- a glossary.

Using this Curriculum

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.

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

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 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.

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

Although the outcomes and indicators in the science curriculum are organized by units of study, teachers may organize their instruction using interdisciplinary themes. Teachers are not required to structure instruction into distinct science units.

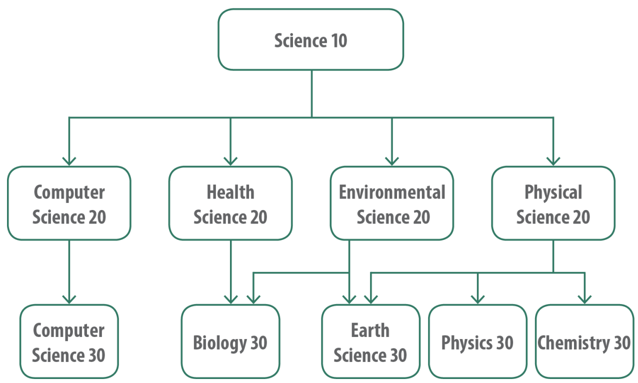
- The term "including" prescribes content, contexts or strategies that students must experience in their learning, without excluding other possibilities. For example, an indicator might say that students should evaluate the relevance, reliability and adequacy of data collection methods, including identifying and explaining sources of error and uncertainty in measurements. This means that, although other methods can be considered, it is mandatory to identify and explain sources of error and uncertainty.
- 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 transportation, sport science or space science" as examples of different motion-related fields. This statement provides teachers and students with possible fields to consider, while not excluding other fields.
- 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, butane, octane, methanol, ethanol and glucose" to refer to the names of common molecular and organic compounds.

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.

Science Pathways Framework



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 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

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.

Related to the following Goals of Education:

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

Sense of Self, Community, and Place

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.

Related to the following Goals of Education:

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

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 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 communicating meaning using various literacies.*

Developing Social Responsibility

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.

K-12 Goals for Developing Social Responsibility:

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

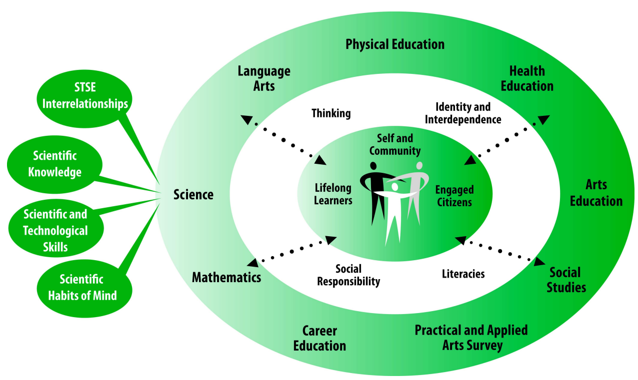
Aims and Goals

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 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)

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.

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)

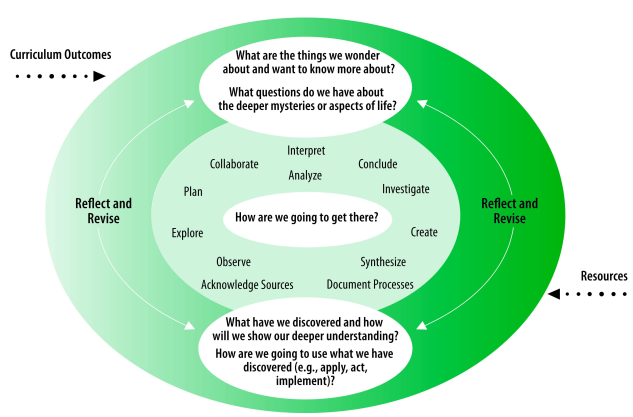
An important part of any inquiry process is student reflection on their learning and the documentation needed to assess the learning and make it visible. Student documentation of the inquiry process in science may take the form of works-in-progress, reflective writing, journals, reports, notes, models,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

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)

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 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.

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.

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)

Science Challenges

Science challenges, which may include science fairs, science leagues, science olympics, 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 Fair. 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 in Canada.

An Effective Science Education Program

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

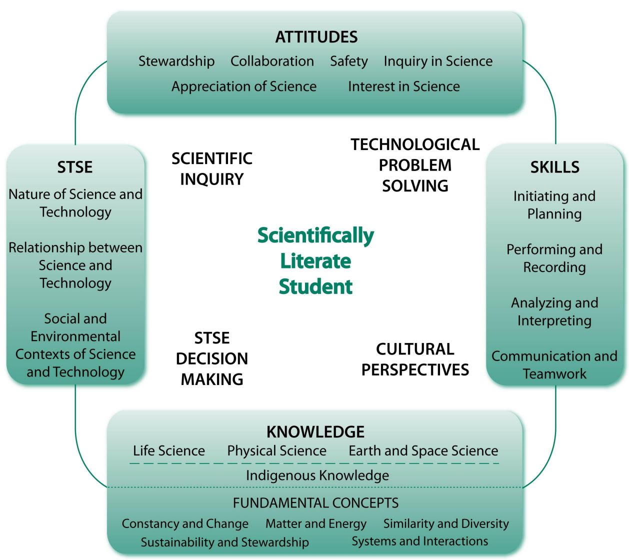
- incorporating all foundations of scientific literacy;
- using the learning contexts as entry points into student inquiry;
- understanding and effectively using the language of science;
- engaging in laboratory and field work;
- practicing safety; and
- choosing and using technology in science appropriately

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 can be used to 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.

<table>
<tr><th colspan="2">Sources of Knowledge about Nature</th></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td>Indigenous 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).</td><td>Scientific KnowledgeSimilar 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.</td></tr>
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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

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.

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).

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 [SI]

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)

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 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.

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)

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.

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)

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

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)

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.

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)

The Language of Science

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

- A **law** is a generalized description, usually expressed in mathematical terms, that describes some aspect of the natural world under certain conditions.
- 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.
- 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 written up 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 written in an essay format or point form rather than using the structured headings of Purpose, Procedure, Hypothesis, Data, Analysis and Conclusion typically associated with a formal lab report. For some investigations, teachers may decide it is sufficient for students to write a paragraph describing 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.

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).

Safety in the science classroom includes the storage, use and disposal of chemicals. The Workplace Hazardous Materials Information System (WHMIS) regulations (WHMIS 1998 and 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 *Materials Safety Data Sheets* (WHMIS 1998) or *Safety Data Sheets* (WHMIS 2015). 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 Health Canada and the Saskatchewan Ministry of Labour Relations and Workplace Safety.

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

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.

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:

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)

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.

Outcomes at a Glance

Student-Directed Study
CH30-SDS1 Create and carry out a plan to explore one or more topics of personal interest relevant to Chemistry 30 in depth

Chemical Bonding and Materials Science
CH30-MS1 Examine the role of valence electrons in the formation of chemical bonds.[SI]
CH30-MS2 Investigate how the properties of materials are dependent on their underlying intermolecular and intramolecular forces.[SI]
CH30-MS3 Explore the nature and classification of organic compounds, and their uses in modern materials. [SI, DM]
CH30-MS4 Determine the suitability of materials for use in specific applications. [DM, TPS]

Chemical Equilibria
CH30-EQ1 Consider, qualitatively and quantitatively, the characteristics and applications of equilibrium systems in chemical reactions. [SI, DM, TPS]
CH30-EQ2 Analyze aqueous solution equilibria including solubility-product constants. [SI]
CH30-EQ3 Observe and analyze phenomena related to acid-base reactions and equilibrium. [SI, DM]

Electrochemistry
CH30-EC1 Investigate the chemistry of oxidation and reduction (redox) reactions. [SI, TPS]
CH30-EC2 Examine applications of electrochemistry and their impact on society and the environment. [SI, DM]

Outcomes and Indicators

Legend

CH30-MS1a	
CH30	Course name
MS	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

Student-Directed Study

Outcome	Indicators
CH30-SDS1 ***Create and carry out a plan to explore one or more topics of personal interest relevant to Chemistry 30 in depth***	a. Design a scientific investigation related to a topic of study in Chemistry 30 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 Chemistry 30. (S, A, K, STSE) c. Assemble and reflect on a portfolio that demonstrates an understanding of a topic of interest related to chemistry. (S, A) d. Design, construct and evaluate the effectiveness of a device, model or technique that demonstrates the scientific principles underlying concept related to a Chemistry 30 topic. (STSE, S) e. Debate an issued related to chemistry, including developing materials to support the arguments for and arguments 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)

Chemical Bonding and Materials Science

Outcome	Indicators
CH30-MS1 ***Examine the role of valence electrons in the formation of chemical bonds.[SI]***	a. Trace the historical development of the model of the atom from Bohr to the modern quantum understanding, including the contributions of Einstein, Planck, Heisenberg and DeBroglie. (STSE, K) b. Discuss the value of representing scientific understanding of the atom using various types of models, including molecular formula, structural formula, space-filling molecular model, ball-and-stick molecular model and Lewis structure. (STSE, A) c. Examine how evidence and experimentation inform the development and refinement of theories in chemistry. (STSE) d. Explain the relationship between the position of an element on the periodic table and its number of valence electrons with reference to the octet rule. (K) e. Explain the formation of ions and predict their charge in group 1 and 2 elements and non-metals, based on an understanding of valence electrons and the octet rule. (K, S) f. Draw Lewis structures (electron dot structures) for group 1 and 2 elements and non-metals, and their ions, based on an understanding of valence electrons. (STSE, S) g. Discuss the role of valence electrons in the formation of covalent and ionic bonds, including the connection to metals and non-metals. (K) h. Predict the arrangement of atoms and draw Lewis structures (electron dot structures) to represent covalent- and ionic-bonded molecules. (S) i. Predict the geometry and draw the shapes of molecules with a single central atom using valence shell electron pair repulsion (VSEPR) theory. (K, S) j. Predict the nature of chemical bonds within a molecule using the property of electronegativity. (K, S)

Outcome	Indicators
CH30-MS2 ***Investigate how the properties of materials are dependent on their underlying intermolecular and intramolecular forces.[SI]***	a. Predict the polarity of molecules using the property of electronegativity and VSEPR theory. (K, S) b. Differentiate between the different types of intermolecular (i.e., van der Waals [i.e., London dispersion, dipole-dipole, hydrogen bonding and ion-dipole], ionic crystal and network-covalent) and intramolecular (i.e., non-polar covalent, polar-covalent, ionic and metallic) forces. (K) c. Recognize that a material's chemical and physical properties are dependent on the type of bonds and the forces between atoms, molecules or ions. (K) d. Identify and describe some properties (e.g., melting point, solubility, thermal conductivity, electrical conductivity, hardness, heat capacity, tensile strength, surface tension, reactivity with acids and bases, flammability, flame tests and odour) of ionic and molecular compounds, metals and network covalent substances. (S) e. Design and carry out a procedure to compare several physical and chemical properties of various materials (e.g., sugar, salt, sand, paradichlorobenzene [mothballs], paraffin and beeswax). (S, STSE, A) f. Construct a classification system of student-tested materials according to one or more properties. (S, STSE, A)f. Construct a classification system of student-tested materials according to one or more properties. (S, STSE, A) g. Determine which intermolecular force is dominant in a student-tested material, based on test results and knowledge of intermolecular forces. (K, S) h. Place new substances into a student-constructed classification system based on their properties. (S, A) i. Recognize the limitations of personal and scientific classification schemes. (STSE, K, A)

Outcome	Indicators
CH30-MS3 ***Explore the nature and classification of organic compounds, and their uses in modern materials. [SI, DM]***	a. Pose questions about the prevalence and diversity of organic compounds in daily life. (STSE, A) b. Explain how the valence structure of carbon leads to the large number and diversity of organic compounds in nature. (STSE, K) c. Describe and compare the advantages of using different models (e.g., molecular, structural, condensed-structural, space-filled, 2-dimensional and 3-dimensional) to represent organic molecules. (K) d. Write the molecular and structural formula and provide the International Union of Pure and Applied Chemistry (IUPAC) name for a representative sample of straight-chain alkanes, alkenes and alkynes, with up to 10 carbon atoms in the molecule. (K, S) e. Provide the IUPAC names, and illustrate, using diagrams, molecular modelling kits and/or digital technology, the structural formulas of a variety of branched- and straight-chain hydrocarbons. (S, K) f. Discuss the importance of isomerization, including geometric and optical isomerization, in materials science and biological applications. (STSE, K) g. Identify various classes of organic compounds based on functional groups including cyclics, aromatics, alcohols, aldehydes, ketones, ethers, esters, organic acids and halocarbons. (S,K) h. Describe applications of the various classes of organic compounds, including compounds (e.g., carbohydrates, lipids, proteins, nucleic acids) important to biological systems. (STSE, K) i. Research how First Nations and Métis people used organic compounds as medicines and to make soap and cleaning products. (STSE, K) j. Provide examples of consumer and industrial products that are derived from the refining of fossil fuels. (STSE) k. Research some societal benefits and environmental impacts related to the petrochemical industry. (STSE) l. Describe processes of polymerization and explain the significance of some natural and synthetic polymers. (STSE, K) m. Design and carry out a procedure to synthesize an organic compound (e.g., soap, esters and polyvinyl alcohol (PVA) polymer slime). (STSE)

Outcome	**Indicators**
CH30-MS4 ***Determine the suitability of materials for use in specific applications. [DM, TPS]***	a. Determine the properties of a material that make it suitable to meet the specifications for a particular product (e.g., catalysts and solvents for oil extraction and refining, metals in equipment for mining, bulletproof fabric, nanotechnologies, superconductors and instant adhesives). (STSE) b. Evaluate the risks and benefits to society and the environment of a product (real or imagined) throughout its life cycle, from raw materials to production, use and disposal. (STSE, A) c. Suggest a range of suitable applications for a material based on its chemical and physical properties. (STSE, K, A) d. Explore how First Nations and Métis people used their understanding of material properties to determine their use (e.g., different species of wood used for burning, smoking and creating structures for housing and transportation). (STSE, K) e. Research First Nations and Métis beliefs regarding the ethical treatment of Mother Earth with respect to the gathering, creating, using and disposing of materials. (STSE, K) f. Identify criteria (e.g., cost, availability, ethics, transportation cost and source of material) used to guide the choice of materials for a specific application. (STSE, A) g. Justify the use of the material chosen for a specific application based on student-selected criteria. (STSE, A) h. Investigate the potential of modern materials (e.g., graphene, aerogels, polymers and carbon nanotubes) to change the way we live. (STSE) i. Analyze how a product (e.g., sporting equipment, vehicle, clothing or building material) has evolved in response to the development of new materials. (STSE, A)

Chemical Equilibria

Outcome	Indicators
CH30-EQ1 ***Consider, qualitatively and quantitatively, the characteristics and applications of equilibrium systems in chemical reactions. [SI, DM, TPS]***	a. Discuss why most chemical reactions do not proceed to completion. (K) b. Discuss the criteria (e.g., closed system, constancy of properties and equal rates of forward and reverse reactions) that characterize an equilibrium system. (K) c. Analyze graphs of the concentrations of reactants and products with respect to time in chemical reactions which approach equilibrium, chemical reactions which achieve equilibrium and chemical reactions which undergo a change in equilibrium. (K, S) d. Write the equilibrium constant (K_{eq}) expression for a variety of chemical reactions. (K, S) e. Recognize that equilibrium constant (K_{eq}) values are dependent upon pressure (for gases only) and temperature but are independent of concentration and the presence of a catalyst. (K) f. Explain why solid and liquid phases have no effect on the value of an equilibrium constant. (K) g. Interpret K_{eq} values to determine whether the concentration of products, reactants or neither is favoured once equilibrium has been reached. (S) h. Perform calculations involving Keq and the equilibrium concentrations of reactants and products. (S) i. Solve problems related to chemical equilibrium, using Initial concentration, Change in concentration and Equilibrium concentration (ICE) charts. (K, S) j. Predict the shifts in equilibrium caused by changes in temperature, pressure, volume, concentration or the addition of a catalyst, using Le Chatelier's principle. (S) k. Construct a model or design an experiment that demonstrates the concepts of equilibrium and/or Le Chatelier's principle. (STSE, S) l. Describe the Haber process, its historical significance and societal impacts. (STSE, K, A) m. Describe ways in which industry manipulates chemical reactions to change the equilibrium point to make processes economically viable. (STSE, K, A) n. Examine how the concepts of reversible reactions and equilibrium apply to biological systems. (STSE)

Outcome	Indicators
CH30-EQ2 ***Analyze aqueous solution equilibria including solubility-product constants. [SI]***	a. Discuss conditions necessary for the establishment of equilibrium in aqueous solutions. (K) b. Analyze how temperature and the common ion effect influence the solubility of substances in aqueous solution. (K, S) c. Predict the changes in solution equilibrium caused by changes in temperature, pressure, volume, concentration or the addition of a catalyst, using Le Chatelier's principle. (S) d. Research applications of solution equilibria in Saskatchewan agriculture, resource extraction, manufacturing and chemical industries. (STSE, K, A) e. Construct solubility graphs from student collected data to demonstrate the effect of temperature on the change in solubility of chemical compounds in water. (K, S) f. Interpret solubility curves of selected substances. (K, S) g. Calculate the solubility product constant (K_{sp}) for saturated solutions, given solute concentrations. (K, S) h. Calculate the solubility of substances in aqueous solutions, given K_{sp}. (K, S) i. Predict whether a precipitate will occur in a double replacement reaction when given the initial concentration of reactants and solubility product constant (K_{sp}) values of the products. (S, K)

Outcome	Indicators
CH30-EQ3 ***Observe and analyze phenomena related to acid-base reactions and equilibrium. [SI, DM]***	a. Identify examples of acid-base reactions in the manufacture and use of consumer products (e.g., foods, cosmetics, pharmaceuticals and cleaners), industrial processes (e.g., resource extraction and refining, mine tailings), agricultural processes (e.g., fertilizer and pesticide application) and First Nations and Métis practices such as tanning hides. (STSE, K) b. Discuss the historical development and limitations of theories, including Arrhenius, Brønsted-Lowry and Lewis, which explain the behaviour of acids and bases. (STSE, K) c. Identify conjugate acids and bases formed in acid-base reactions using Brønsted-Lowry theory, including substances which are amphiprotic (amphoteric). (S, K) d. Differentiate between strength (strong versus weak) and concentration (concentrated versus dilute) when referring to acids and bases. (S) e. Classify strong and weak acids and bases using the magnitude of K_a and K_b. (S, K) f. Discuss the relationship between $[H^+]/[H_3O^+]$ and $[OH^-]$ in the dissociation of water, to explain K_w and perform relevant calculations. (K, S) g. Solve problems involving pH, pOH, $[H^+]/[H_3O^+]$, [OH-], K_w, K_a and K_b. (S) h. Explain how acid-base indicators function chemically, using Le Chatelier's principle. (K, STSE) i. Estimate the pH of solutions using acid-base indicator solutions and indicator papers. (S, K) j. Design and carry out an experiment to differentiate between weak and strong acids using indicators. (S, K) k. Perform acid-base titrations and relevant calculations for multiple ratios of $[H^+]/[H_3O^+]$ to [OH-], including those for reactions that either reach the endpoint/equivalence point or represent over-titration. (S) l. Interpret pH titration curves for various combinations and strengths of acids and bases, by identifying endpoints and choosing appropriate indicators. (STSE, S) m. Discuss the role of acid-base buffering as an aspect of maintaining homeostasis in biological systems. (K)

Electrochemistry

Outcome	Indicators
CH30-EC1 ***Investigate the chemistry of oxidation and reduction (redox) reactions. [SI, TPS]***	a. Compare the characteristics of oxidation-reduction (redox) reactions with other types of chemical reactions. (STSE, K) b. Define oxidation and reduction and oxidizing and reducing agents in terms of electron transfer. (K) c. Write and balance redox equations using the half reaction and oxidation number method. (K, S) d. Create a reduction potential series based on student-collected data. (STSE, S) e. Illustrate and label the parts of electrochemical and electrolytic cells and explain how they work, including half-reactions, flow of ions and flow of electrons. (K, S) f. Differentiate between electrochemical and electrolytic cells in terms of spontaneity, direction of electron flow, energy, charge on electrodes and chemical change. (K, S) g. Predict the electric potential and spontaneity of various redox reactions using reduction potentials. (K, S) h. Design, construct, and evaluate a prototype of a working battery that meets specific student-identified criteria such as powering a small electric device. (STSE, S)

Outcome	Indicators
CH30-EC2 ***Examine applications of electrochemistry and their impact on society and the environment. [SI, DM]***	a. Provide examples of oxidation-reduction (redox) reactions that occur in nature and in technological processes. (STSE, K) b. Evaluate the economic importance of electrochemical technologies and processes. (STSE, K, A) c. Investigate the impact of the electrochemical industry on the environment, including disposal of raw materials, batteries and mine tailings. (STSE, A) d. Design and carry out experiments which illustrate the processes of electrolysis and electroplating. (S, K) e. Investigate the process of corrosion and its prevention (e.g., painting and coating, cathodic protection, alloys, sacrificial anodes and avoiding incompatible metals). (STSE, K) f. Examine the role of oxidation and reduction in biological processes (e.g., photosynthesis, respiration and the action of antioxidants). (STSE, K) g. Research the role of oxidation and reduction in First Nations and Métis practices (e.g., drying and smoking meat for preservation). (STSE, K) h. Explain how electrical energy is produced in hydrogen fuel cells and various types (e.g., lead-acid, nickel-cadmium, alkaline and lithium-ion) of batteries. (STSE, K, A) i. Research and discuss the issue of storage of electrical energy as a barrier to large scale adoption of renewable energy resources. (STSE, K, A)

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

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

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.

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.

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

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