General Learning Outcome D

Essential Concepts

GLO D

Explore, understand, and use scientific knowledge in a variety of contexts.

Overview

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge. Many of the following suggestions for instruction have been developed from the recommendations found in the *Pan Canadian Science Framework* (Council of Ministers of Education, Canada). Teachers are encouraged to access this document to develop a greater appreciation for the changing role and purpose of acquiring scientific knowledge in today's school science environment.

The subject matter of science includes theories, models, concepts, and principles that are essential to a working understanding of the life sciences, physical sciences, geosciences, and space sciences. Content knowledge can provide an informed basis for exploring essential learning, and it will be increasingly important for students of science to make interdisciplinary connections among and within the science disciplines. Ultimately, we desire to answer for a particular place and time the question: "What knowledge from science is of most worth?" There is no definitive answer to such a complex and opinion-ridden question, and so we leave this to the professional discretion of those particular places and the students who live in them.

Specific Learning Outcomes

SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.

SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.

SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.

SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

General Learning Outcome D	Specific Learning Outcome
Students will… Explore, understand, and use scientific knowledge in a variety of contexts.	**SLO D1:** Use the concepts of similarity and diversity for organizing our experiences with the world.

Suggestions for Instruction

Similarity and Diversity

The concepts of similarity and diversity provide tools for organizing our experiences with the 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 they encounter, thus enabling them to share ideas with others and to reflect on their own experiences (Council of Ministers of Education, Canada 16).

Illustrative Example 1:

Analyze the patterns and products of evolution.

Science attempts to provide an explanation for the origin and evolution of life on Earth. Evidence for evolutionary change can be found in things such as fossil records, plate tectonics, and DNA samples.

Activating Prior Knowledge

- Students discuss possible evolutionary relationships between familiar groups of organisms, such as mammals or flowering plants. *What structural features have changed the most over time? What evolutionary evidence exists for the ancestry of a modern animal or plant?*

Acquisition and Development of Concepts

- Students trace the ancestry of the modern horse from Eohippus(?), which may never have existed, to Equus to determine the historical changes required in its evolution from a small, woodlands browser to a large, plains-dwelling grazer. If students are provided with illustrations (drawings, photographs, art) that compare possible changes in anatomy, such as size, leg anatomy, and tooth anatomy, they can evaluate evidence for the theory of evolution. *How are dietary changes linked to changes in tooth anatomy? What advantages would a tall horse have as a plains dweller? Why would running be necessary for a plains dweller? How did changes in the environment result in an evolutionary adaptation?*
- Students research and develop a large timeline, drawn to scale, showing the history of the science of evolution (dates, major advances in evolutionary knowledge, names).
- Students research and debate Lamarckism versus Darwinism.
- Students choose a common structure, such as bird beaks or wings, and compare the evolutionary adaptations between species.

Application

- Students investigate and report on the evolution of the cat, dog (or other household pets), and/or other domesticated animals used in agriculture.
- Students visit a local museum that contains the paleontological story of various animals or plants.
- Students videotape and share with the class a story of a chosen organism.
- Students investigate the role of mitochondrial DNA in the study of evolution.
- Students investigate the role of humans in the evolution of the modern dog.
- Students examine the chemical composition of an evolutionarily similar structure such as hair, nails, and feathers.

Suggestions for Instruction

Illustrative Example 2:

Identify and explain the diversity of organic compounds and their impact on the environment.

Organic chemistry is an important component of the study of biochemistry, bioengineering, medicine, and synthetic chemistry. Students should be aware of the process whereby carbon-bearing resources are converted into basic organic molecules that are then turned into a wide variety of plastics, fuels, and pharmaceuticals.

Activating Prior Knowledge

- Students identify different synthetic organic compounds in their classroom, in their homes, and in the environment. As well, students identify how many of the organic compounds are harmful or helpful to living things. *What are the risks and benefits to society and the environment of developing new synthetic products?*

Acquisition and Development of Concepts

- Students study the unique properties of carbon, focusing on the bonds that form between carbon atoms. Bond characteristics that may be considered include: strength, numbers (single, double, or triple bonds), and structure (long, straight, or branched chains or ring). Students build, draw, and name models of a variety of organic compounds.
- Students research the historical development of medicinal products, starting with crude extracts from plant sources. *Why are plants valuable resources? What are some modern medicines that have been developed from ancient remedies? What are the active ingredients? What are the different purifying methods?*

Application

- Students carry out a risk-benefit analysis of activities that produce dioxins as by-products. These activities could be the burning of household waste in the backyard, the incineration of toxic wastes, or various industrial processes. *What effect do dioxins have on living organisms?*
- Students choose a synthetic material and carry out a practical investigation of some of its properties, such as physical strength, effect of solvents, and combustibility. In conjunction with the investigation, students obtain and present information related to the properties, cost, uses, possible hazards, means of production, and social and economic implications of the chosen material.
- Students synthesize an organic compound such as acetylsalicylic acid (ASA), nylon, or an ester.
- Students draw the chemical structure of medicinal compounds and describe the specific part of the structure that is associated with its medicinal activity.

Illustrative Example 3:

Demonstrate an understanding of solutions and stoichiometry in a variety of contexts.

It is important for students to understand that most chemical reactions involve chemicals dissolved in a medium, such as water. Learning opportunities involving the nature of solutes, solvents, the mole concept, balancing equations, and stoichiometry enable students to gain a better understanding of the nature of chemical reactions.

Activating Prior Knowledge

- Students compare properties of different kinds of solutions using various technologies, and establish classes of solutions, such as electrolyte/non-electrolyte or acid-base. The importance of controlling concentration can be illustrated by reminding students that a very low fluoride ion concentration is beneficial since it inhibits dental decay, but a concentrated fluoride solution is highly toxic. *Why is the ability to predict the type and quantity of products in a reaction important for a scientific investigation or a chemical-industrial process?*

Acquisition and Development of Concepts

- Students perform calculations dealing with molar concentration of a solution, leading to the preparation of an ionic solution of known concentration. The use of appropriate equipment, such as a balance, volumetric flask, funnel, and beaker, to prepare such a solution should be emphasized.

Suggestions for Instruction

- Students predict, using the method of stoichiometry, the quantity of a reagent used or produced in a chemical system, given a specific quantity of another reagent used or produced in that reaction.
- Students perform quantitative investigations to test the predictive ability of the stoichiometric method and quantitative analyses to determine an unknown quantity in a chemical system, such as the unknown concentration of a solution or the unknown mass of a solute.

Application

- Students discuss with an industrial chemist the usefulness of the stoichiometric method in science and technology in industrial applications.
- Students research the importance of stoichiometry in pharmacology.
- Students determine, based on chemical composition, why certain foods are more efficient at providing energy than others.
- Students determine, based on stoichiometric principles, what type of heating system is the most efficient to install in a home.
- Students investigate how airbag designers use stoichiometry to determine the right composition of gas.

Illustrative Example 4:

Describe the nature of space and its components and the history of the observation of space.

The stars and other celestial objects have long held a fascination for humans. From the earliest times of recorded history, humans have attempted to explain what is in space. Through various learning activities, students identify and describe the various components of the universe and develop an appreciation of the vast distances between these components.

Activating Prior Knowledge

- Students engage in a general discussion or brainstorming session about the nature of the universe. This should lead to the identification of recent advances in technology, such as optical, radio, and orbiting telescopes, that have allowed astronomers to observe the various components of the universe and to speculate on what has happened in the past and what might happen in the future. *How are other stars similar to and different from the sun? What do we know about the universe? What are we trying to find out?*
- Students develop a chronology of space discovery and exploration.

Acquisition and Development of Concepts

- Students use the Hertzsprung-Russell diagram to study theories of stellar evolution. This could lead to a discussion of the frequency of stars similar to our sun and the possibility and probability of other planets similar to Earth.
- Students develop an appreciation of the size of the universe and the vast number of stars and other components. Students should be able to understand the idea that because of the vast distances in space, the light reaching our eyes and our instruments is millions of years old, and therefore our present view of distant objects in space is actually a look back in time.
- Students examine the Nebular Hypothesis of the formation of the solar system.
- Students investigate the relationship between Earth and its single moon. *How and why are they different? How did they come to orbit around each other?*
- Students find out how astronomers determine the composition, age, and history of a planet or a star.

Application

- The study of star formation and evolution may help students understand the chemistry of Earth’s rocks, air, water, and life. Students speculate about the possibility of life elsewhere in the universe. This could lead to a discussion of the necessary requirements for human life, and of the idea that different life forms may have different requirements.
- Students investigate the possibility of living in space.

General Learning Outcome D	Specific Learning Outcome
Students will... Explore, understand, and use scientific knowledge in a variety of contexts.	**SLO D2:** Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.

Suggestions for Instruction

Systems and Interactions

An important part of understanding and interpreting the world is the ability to think about the whole in terms of its parts and, alternately, about parts in terms of how they relate to one another and to the whole. A system is a collection of components that interact with one another so that the overall effect is much greater than that of the individual parts, even when these are considered together (Council of Ministers of Education, Canada 16).

Illustrative Example 1:

Compare and contrast mechanisms used by organisms to maintain homeostasis.

Note: This topic is treated in significant detail in Manitoba's Senior 3 Biology curriculum. Teachers are encouraged to consult *Senior 3 Biology: A Foundation for Implementation* (Manitoba Education, Citizenship and Youth) for detailed approaches to the topic.

All living organisms struggle to maintain an internal balance in response to the constant pressure of external phenomena. Students should be provided with a variety of opportunities to study different factors affecting an organism's homeostasis. Through this study, students begin to appreciate the complexity of mechanisms involved in homeostatic regulation.

Activating Prior Knowledge

- Students discuss how organisms (plants and animals) survive some of the severe weather and climate conditions in Canada. *How do plants use homeostatic mechanisms to adapt and survive? What adaptive mechanisms have been developed by organisms such as fish, frogs, and plants to survive in extreme weather conditions?*

Acquisition and Development of Concepts

- Students research, design, and/or conduct experiments to investigate: the transpiration tension theory of vascular plants; behavioural adaptations; tropisms such as hydrotropism, geotropism, chemotropism, and phototropism; and the effect of growth hormones on plants.
- Students inquire into the following question: *How do gardeners, horticulturalists, agriculturalists, and tree technologists promote plant adaptation and survival for use by human communities?*
- Students choose a particular animal species and investigate an environmental adaptation (for example, to heat, cold).
- Students discuss the importance of wetlands in maintaining homeostasis in the environment.

Extension

- The University of Manitoba operates a Laboratory for Exercise and Environmental Medicine, in which Dr. Gordon Giesbrecht studies human responses to exercise/work in extreme environments. He has conducted hundreds of cold water immersion studies that have provided valuable information about cold stress physiology and pre-hospital care for human hypothermia. Dr. Giesbrecht has undertaken a number of unique projects, such as a Lake Winnipeg Marathon on Ice. Students may be interested in finding out what Dr. Giesbrecht's most current project is.

  Contact information:

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Suggestions for Instruction

Application

- Students choose a plant, propagate it, and assist its homeostatic mechanisms to help the plant survive in the conditions of its home.
- Students research hardiness zones in Canada, and describe how some plants can survive in certain zones when others cannot.
- Students examine what happens when kidneys malfunction in a human.
- Students research the contribution of the immune response to homeostasis.

Illustrative Example 2:

Evaluate relationships that affect the biodiversity and sustainability of life within the biosphere.

Note: This topic is a primary focus of Manitoba's Senior 4 Biology curriculum. Teachers are encouraged to consult *Senior 4 Biology: A Foundation for Implementation* (Manitoba Education, Citizenship and Youth) for detailed approaches to this topic.

At the biome and ecosphere levels of biological organization, there are many complex interactions between biotic and abiotic factors. Building on their understanding of ecosystems and certain principles of population dynamics, students need to understand the many interrelationships affecting population growth.

Activating Prior Knowledge

- Taking an example of a local/regional endangered species, students review the determiners of population: natality, mortality, emigration, and immigration. Students then brainstorm factors that affect human natality and mortality. *Why should we be concerned about Earth's carrying capacity for the human population?*

Acquisition and Development of Concepts

- Students use graphs located in resource materials or constructed from data tables to illustrate the historical growth of human population based on estimated data. They project the graph line into the future as an exercise of prediction and extrapolation in terms of linear or exponential growth and doubling of time.
- Students obtain and graph data of a particular species of organism, such as a local fish, and then interpret the graphs.
- Students research and debate the role of zoos in maintaining biodiversity.

Application

- Students identify which social and environmental factors need to be considered and changed locally, regionally, and globally to create a sustainable human population for planet Earth.
- Students research and then debate the ethics of human population control.
- Students plan and carry out a terrestrial or an aquatic biodiversity study.
- Students use environmental census data to study the state of a threatened species and present a plan to maintain the species.

Illustrative Example 3:

Demonstrate an understanding of the characteristics and interactions of acids and bases.

Students regularly use solutions that include acids and bases. It is important that they be able to demonstrate their understanding of acids and bases by appropriately selecting the proper acid and base to use for a given task. As well, students should be aware of the potential effects these chemicals could have on the environment. Students' knowledge and interests are enhanced when they understand the relationship between acid-base theories and certain acid-base reactions that take place around them.

Activating Prior Knowledge

- Students identify common products involving acids and bases, such as shampoos, foods, and household cleaners. They should be encouraged to speculate as to how acids and bases react in the situations they identify. *Why are specific acids and bases used in particular instances?*
- Students research and discuss the causes and effects of acid rain.

Suggestions for Instruction

Acquisition and Development of Concepts

- By studying the historical development of acid-base theory, students will be able to show how theories evolve in light of new experimental evidence.
- Students formulate an operational definition of acids and bases based on laboratory observations.
- In a laboratory setting, students determine the concentration of an acid or a base, the citric acid concentration of a citrus fruit, or the acetylsalicylic acid (ASA) content of a headache medication tablet.

Application

- Students address an environmental issue pertaining to acids and bases. Working as a team, they present factual arguments representing various perspectives.
- Students examine how the understanding of the chemistry of hair care, including pH, helps in the development of better hair-care products.
- Students determine how the acidic or basic nature of soils is important in the growth of food crops.

Illustrative Example 4:

Illustrate and explain the various forces that hold structures together at the molecular level, and relate the properties of materials to their structures.

Modern chemistry is directly involved in the development of new materials. Depending on their intended applications, materials can now be synthesized according to specific properties such as weight, resistance to heat, flexibility, malleability, and electrical conductivity. To synthesize a new material, it is often necessary to have an understanding of the electron arrangement, and thus the type of bonding, in the material. For students, knowledge of the nature of bonding is important because bonds are ultimately responsible for a substance's physical and chemical properties.

Activating Prior Knowledge

- Students identify changes in the composition of materials and the structure of common objects. The evolution of the bicycle and the automobile are good examples of how characteristics of materials, such as being lightweight and rust-resistant, have improved the efficiency of these vehicles. *What other materials demonstrate useful properties? How does the nature of bonds determine a material's properties?*

Acquisition and Development of Concepts

- Students predict and explain the different types of intramolecular forces and intermolecular forces for a given compound. They use accepted models to illustrate these forces. They also use established conventions to name and represent the studied compounds. Important work by scientists relating molecular structure to its properties can be emphasized in this area of study.

Application

- Students research some modern materials, such as composites, resins, alloys, and ceramics, and relate the properties of these materials to the bonds.
- Students research and design a structure, such as a bridge, where the type of material used is critical in its construction.

Illustrative Example 5:

Explain the fundamental forces of nature, using the characteristics of gravitational force and electric and magnetic fields.

Television is used in conjunction with video cameras, videodiscs, and videocassette recorders for a wide variety of purposes, including entertainment, education, engineering, and medicine. These electrical devices use the principles of electromagnetism and energy to produce an image on a screen. Students should be able to apply these principles to the functioning of TV picture tubes.

Suggestions for Instruction

Activating Prior Knowledge

- Using a direct current (DC) power source, wire, solenoid, and compass, students investigate the characteristics of magnetic fields. Using an electron tube, they can observe the effects of a magnet on the electron beam.
- Students use print and electronic sources to investigate the development of television/LCD flat-screen technology. *Is the quality of the image produced by a 27 in. (68.6 cm) screen better than that produced by a 54 in. (137.2 cm) screen? Why?*
- Students examine the gravitational forces affecting planets and satellites in the solar system. *How do gravitational forces affect us daily?*

Acquisition and Development of Concepts

- Students analyze, both qualitatively and quantitatively, the forces produced as a result of electric current flowing through a wire. They determine what factors are responsible for increasing and for decreasing the force on the moving charge.
- Students develop a plan to compare the quality of the picture for smaller and larger screen sizes by identifying specific major variables and criteria.
- Students describe the role of magnetism in solar phenomena such as sunspots.

Application

- Students list the design difficulties involved in manufacturing a 54 in. (137.2 cm) flat-screen TV compared to those involved for a 27 in. (68.6 cm) screen, as well as the changes that would need to be made to the design if the quality of the picture for a 54 in. (137.2 cm) set were to match that of a 27 in. (68.6 cm) set.
- Students determine whether it would be in a buyer's best interests if the flats-screen TVs manufactured for North America renewed the colour screen 60 times a second, rather than the current 75 times per second.
- Students explain the synchronization of the cathode-ray tube with TV cameras and TV sets.
- Students plan a trip near a black hole. What will be the effect of the *gravitational force?*
- Students research the role of the magnetic field on animal migration.
- Students build a solar cell, explaining how light energy is converted into electric energy.
- Students explain how a microwave works.

Illustrative Example 6:

Describe and predict the nature and effects of changes to terrestrial systems.

Earth contains a variety of complex, yet interconnected, systems. The major systems are generally referred to as Earth's spheres: atmosphere, hydrosphere, lithosphere, and biosphere. Within each sphere are other systems or subsystems.

Activating Prior Knowledge

- Students investigate each of Earth's systems to identify their general characteristics. These investigations could include: monitoring weather patterns using appropriate tools and procedures; identifying and classifying rocks and minerals; analyzing oceanographic data; and studying local examples of erosional activity. *How do the atmosphere and hydrosphere interact in the water cycle?*

Acquisition and Development of Concepts

- Students describe the physical processes of evaporation, condensation, and precipitation, including the energy transferral that takes place in each process. Using this information, they explain common weather phenomena such as rain, thunderstorms, hurricanes, and tornadoes. They should be able to demonstrate an understanding that, while the hydrosphere and the atmosphere may be described separately, they are inextricably linked.
- Students write a story from the perspective of a water molecule and, in the context of the story, thoroughly explain the water cycle.
- Students go on a field trip to examine local effects of erosion.

Suggestions for Instruction

Application

- For outdoor activities, knowledge of the weather and weather systems is very useful. To become familiar with predicting weather, students develop possible weather scenarios describing some atmospheric conditions. They then challenge classmates to predict what the effects of those conditions could be on weather for the short term and the long term.
- Students develop a plan to control erosion in a local area.

Illustrative Example 7:

Demonstrate an understanding of the formation of Earth, its history, and its geologic change.

Recent scientific and technological developments have enhanced our understanding of the history of Earth, but at the same time they have raised more questions. Since the human perception of time deals with relatively short periods, geologic time is a difficult concept for students to understand and appreciate. However, the concept of geologic time is critical for understanding concepts such as the formation of planets, the movement of continents, the changing of climates, the evolution of organisms, and the development of mountains.

Activating Prior Knowledge

- Students participate in a discussion of different explanations of the origin and the age of Earth, from religious and cultural explanations to the big-bang theory. In exploring these ideas, students need to examine the evidence that has been collected to support the various explanations and to make their own judgements about the relative merits of each. *How have science and technology helped humans attempt to determine particular events in Earth's history?*

Acquisition and Development of Concepts

- Relative ages of rocks and events in Earth's history can be determined by applying basic Earth science concepts such as uniformitarianism, original horizontality, and superposition. To determine relative dating or sequencing of events, students should examine and interpret geological cross-sections that exhibit folding, faulting, intrusions, and erosion.
- The age of individual events or objects from Earth's history can be determined by various radiometric dating techniques.
- A radioactive decay simulation activity using coins or other appropriate objects would help students understand the concepts of radioactive decay, isotopes, and half-lives.

Application

- Students analyze a fictional geological cross-section and use other data generated by relative dating to identify the age of particular fossils.
- Students research and debate issues surrounding climate change.

Illustrative Example 8:

Demonstrate an understanding of the relationships among systems responsible for changes to Earth's surface.

Geophysical studies of Earth have generated evidence that Earth's interior is a dynamic, moving environment that has caused mountains to rise, basins to sink, and entire land masses to move, resulting in continual rearrangement of the surface of the continents and the configuration of the oceans. These processes, which modify the shape of Earth's surface, form the basis of the plate tectonic theory. Students can develop an understanding of plate tectonic theory by examining various Earth processes.

Activating Prior Knowledge

- Students identify the location of global features such as mid-ocean ridges, marine trenches, island arcs, mountains, and volcanoes, and hypothesize why these features are located where they are. *How does an understanding of plate tectonic activity benefit humankind?*

Acquisition and Development of Concepts

- Students study the distribution of global features such as mid-ocean ridges, marine trenches, island arcs, mountains, and volcanoes.

Suggestions for Instruction

- Students analyze the types of plate margins and correlate various features with a specific type of margin.
- Students use the Internet to gather information about recent earthquake or volcanic activity, or about other risks associated with geological processes.
- Students explore the tools and techniques used to study the processes that change the lithosphere. These tools and techniques could include aerial photographs, satellite photographs, computer-enhanced images, radar, and computer modelling.
- Students analyze seismographic data to determine the epicentre of an earthquake.

Application

- Knowledge of earthquakes and information gathered from past experience may be used to create an emergency-response plan for a community located in a geologically active area.
- Students devise a set of construction guidelines for public buildings or homes, or guidelines governing the types of housing allowed in a geologically active area.

Teacher Notes

General Learning Outcome D	**Specific Learning Outcome**
Students will… Explore, understand, and use scientific knowledge in a variety of contexts.	**SLO D3:** Understand the processes and conditions in which change, constancy, and equilibrium occur.

Suggestions for Instruction

Constancy and Change

The concepts of constancy and change underlie most understandings of the natural and technological world. Through observations, students learn that some characteristics of materials and systems remain constant over time (e.g., the speed of light or the charge on an electron), whereas other characteristics change. Through formal and informal studies, students develop an understanding of the nature of things, and of the processes and conditions in which change takes place (Council of Ministers of Education, Canada 16).

Illustrative Example 1:

Compare and contrast the reproduction and development of representative organisms.

Reproduction is an essential process for all living organisms. Besides understanding some principles of how living organisms reproduce, students can begin to appreciate the complexity and impact of reproductive technologies. Analysis, from a variety of perspectives, of the risks and benefits of these technologies creates opportunities for students to apply scientific knowledge, skills, and attitudes in meaningful situations.

Activating Prior Knowledge

- Animal husbandry has revolutionized the use of in vitro fertilization techniques. The reproductive rates of valuable livestock have increased dramatically, as have beneficial traits in new breeds. Students consider the following techniques and identify those they have heard about: superovulation of donor with gonadotrophins; artificial insemination (AI); non-surgical removal of embryos; transfer of embryo to surrogate; and birth after embryo transfer. *Should biotechnology be used for rapid propagation of endangered species? Should cloning be used to replicate an organism?*

Acquisition and Development of Concepts

- Students research and debate the following statement: *If the most desirable domestic animals are able to parent an entire herd in each reproductive cycle, could this technique be applied to endangered species?* (In April 1990, Mary Alice, a rare Siberian tiger, was born as a result of *in vitro* fertilization technology.)
- Students interview a reproductive technologist using questions such as the following: *Should endangered species be preserved? At what cost? Who decides? Might this technology result in an uncontrolled monster?*
- Students research and debate the application of reproductive technologies in humans.

Application

- To evaluate the potential application of their findings, students might complete a risk/benefit analysis of the desirability of preserving endangered species by considering the following: safety, efficiency of practice, quality of life, and cost-effectiveness.

Suggestions for Instruction

Illustrative Example 2:

Demonstrate an understanding of the structure and function of genetic materials.

Much of the structure and function of every living organism is determined by genetic material. It may be important for a scientifically literate person to understand certain principles and fundamentals related to genetic material: what its make-up is, how humans are manipulating it, and why this major area of scientific and technological endeavour has implications for humans and planet Earth.

Activating Prior Knowledge

- Students brainstorm ideas about genetic material and discuss their preconceptions. They then assemble their ideas and show the interrelationships between these ideas on a Concept Web/Map, based on their current understanding. *How can the principles of genetics be applied to a case study such as the Human Genome Project completed in 2002?*

Acquisition and Development of Concepts

- Students extract DNA from onions or bacteria.
- Students research tools and techniques used to study genetics. Areas of research to consider include: the polymerase chain reaction (PCR) process, DNA fingerprinting, gene probes, recombinant DNA, cloning, genetic markers, and gene mapping.
- Students separate DNA using electrophoresis.

Application

- Students conduct a major research report on the Human Genome Project. Using a variety of print and electronic sources, they could consider the following areas: *How and why was the Human Genome Project conducted? What are the implications of decoding the complete human genome? What are potential career pathways that would enable a student to participate in the fruits of the Human Genome Project?*
- As a follow-up activity to the report, students debate the issue of whether society should support projects such as the Human Genome Project.

Illustrative Example 3:

Use the redox theory in a variety of contexts related to electrochemistry.

Students often use electrochemical applications in their everyday lives. By studying the design and function of various electrochemical technologies, students will better comprehend the relationship between science and technology with regard to the progress, evolution, and many uses of electrochemical cell technology. Other electrochemical processes and applications such as corrosion, corrosion protection, and electrolysis can also be studied within this context.

Activating Prior Knowledge

- Students discuss the different uses of batteries they have observed in daily life. Examples could include the use of batteries and electrochemical cells in cars, pacemakers, hearing aids, and electronic equipment. They could also mention differences in these batteries and cells, such as the difference between rechargeable and alkaline cells. *How can we increase the efficiency of electrochemical cells for everyday use?*

Acquisition and Development of Concepts

- Students manipulate and “dissect” several types of batteries and electrochemical cells. This would allow students to compare the internal structures and help them explain how each battery or electrochemical cell works in terms of electrochemical principles.
- Students design and build an electrochemical cell with a predicted voltage.
- Students test the electrochemical cell for the predicted voltage and suggest possible ways to increase the cell’s efficiency.

Application

- Students work in teams to report on the use of electrochemical cells in a variety of contexts. The teams evaluate the appropriateness of these applications.
- Students work collaboratively to design and build an electrochemical cell to power a small, motor-driven device or a flashlight, and identify ways to maximize its efficiency.

Suggestions for Instruction

Illustrative Example 4:

Analyze and describe relationships between force and motion.

Force and motion affect our lives, whether we are driving a car or riding a roller coaster at an amusement park. Newton's laws of motion were revolutionary because they explained the behaviour of moving objects and systems on Earth and in the universe. Students should be provided with various situations involving examples of Newton's laws.

Activating Prior Knowledge

- Students request specifications from manufacturers on the design and function of safety devices such as seat belts, infant car seats, and airbags. Using these specifications, students discuss how the safety devices counteract the effect of the forces developed during a collision. *What physics principles govern the design of safety devices such as airbags?*

Acquisition and Development of Concepts

- Using the scenario of an automobile colliding with a wall, students identify the forces that would act on the car and its passengers, including different speeds at the time of the accident, the mass of the car, and the use or non-use of safety devices.
- Students identify the scientific principles and assumptions about human behaviour that underlie the design of safety devices.

Application

- Students consider whether it is a good idea for manufacturers to allow airbags to be disabled, or to increase the airbag activation speed from the current 30 km/h to 55 km/h, and lower the acceleration of airbag deployment from 300m/s to 210m/s.
- Students suggest ways to increase the levels of compliance for the use of safety devices such as seat belts, infant car seats, and airbags.
- Students design and construct a model roller coaster.

Illustrative Example 5:

Predict and explain interactions between waves and matter, using the characteristics of waves.

Understanding mechanical waves such as sound has artistic and aesthetic implications. For example, computers equipped with sound cards can produce musical sounds that are similar to the sounds produced by conventional musical instruments. The problem for software designers is to make the computer generate a realistic reproduction of the sound of a musical instrument. It is important to make students aware of the basic principles of sound and to encourage them to explore these phenomena through the use of concrete materials.

Activating Prior Knowledge

- Students use a variety of instruments to produce the note middle C. For example, students could listen to pure middle C and middle C sounds produced using computer .wav files. They then describe each sound produced. *How can you make a computer produce a middle C sound that is indistinguishable from that produced by a grand piano?*

Acquisition and Development of Concepts

- Students use terms such as *pitch*, *tone*, *frequency*, and *frequency mixing* to describe the similarities and differences between the sounds produced by the different instruments.
- Students use the computer sound card to produce different sounds through the process of mixing a middle-C frequency with other frequencies.
- Students use the oscilloscope to produce graphs of the sounds produced by different instruments.
- Students use the method of trial and error in the mixing process to make the computer produce the same graphs produced by the grand piano for middle C.
- Students examine the formation of "tidal" (seismic sea) waves.

Application

- Students create sound profiles for different instruments, using the appropriate technology.
- Students use the computer to create printouts of musical notation that correspond to sounds produced by the sound card.

General Learning Outcome D

Students will...

Explore, understand, and use scientific knowledge in a variety of contexts.

Specific Learning Outcome

SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

Suggestions for Instruction

Energy

The concept 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. Students learn to describe energy in terms of its effects and, over time, develop a concept of energy as something inherent within materials and in the interactions between them (Council of Ministers of Education, Canada 16).

Illustrative Example 1:

Determine how cells use matter and energy to maintain the organization necessary for life.

A living thing is more than a set of chemical reactions or a physical machine. Much knowledge about living systems has been derived by studying cellular metabolism and the physical processes that occur within a cell. Students should have some appreciation for the complexity of life at the cellular and molecular levels of organization.

Activating Prior Knowledge

- Students discuss the four groups of fundamental biochemicals: carbohydrates, lipids, proteins, and nucleic acids. *What are the characteristics of the fundamental groups of biochemical molecules that are so important to life? How do cells get energy?*

Acquisition and Development of Concepts

- Students identify carbohydrates, lipids, and proteins through a variety of tests and indicators.
- Students use a calorimeter to measure the amount of energy (kcal) in foods.
- Students measure the metabolic rate of a unicellular organism and extract DNA.
- Students examine the process of metabolism, including the role of adenosine triphosphate (ATP).

Application

- Students conduct an interview with a biochemist to learn more about career opportunities in this field.
- Students research which micro-organisms are used to make certain biochemical products such as hormones and drugs.
- Students inquire into how various biochemical molecules are involved in cellular structures and processes.

Illustrative Example 2:

Predict and explain energy transfers in chemical reactions.

In Canada, many electrical power plants depend on the combustion of fuels such as coal, diesel, woodchips, and natural gas. As the production of energy and subsequent use of that energy costs money, there is a need to ensure an efficient process for producing and using energy. Students should be provided with opportunities to study the concept and issues of having heat to generate electricity.

Activating Prior Knowledge

- Students compare different ways of producing electricity in Canada. Various sources of energy, such as nuclear energy, hydroelectricity, wind energy, and others, will probably be mentioned, but the focus should be on the methods that use combustion reactions. *Which fuel is best to use in electric power plants?*

Suggestions for Instruction

Acquisition and Development of Concepts

- Students predict the amount of heat generated in a variety of combustion reactions using bond energies, heats of formation, and Hess's law. Their calculations leading to the predictions can be communicated graphically using potential energy diagrams.
- Students carry out experiments using basic calorimetry to measure the heat used or produced in a variety of chemical reactions. They then compare their experimental results with their predictions.

Application

- Students visit a power plant to gain a greater appreciation of the scope and complexity of the technology involved. They then relate their understanding to direct technological applications and potential careers.
- Students prepare a report recommending the use of a particular fuel for a power plant. In their recommendation, they take into account a comparison of the emission of greenhouse gases and other pollutants from the reactions. The report should also contain references to economic, scientific, technological, ecological, and ethical perspectives, as well as the issue of sustainability.

Illustrative Example 3:

Analyze and describe different means of energy transmission and transformation.

In their daily lives, humans are exposed to radiation from a variety of sources. In some situations, radiation (such as an X-ray) is beneficial, and in other situations, radiation (such as that from the sun) is potentially harmful. Students assess the risks and benefits of exposure to radiation from natural and artificial sources.

Activating Prior Knowledge

- Students perform an activity using readily available materials such as coins, coloured chips, and candies to demonstrate radioactive half-life, and draw a graph. This graph can then be related to decay curves, taken from reference sources, for other radioactive substances.
- Students work collaboratively to develop a plan for appropriate sampling procedures to determine the levels of radiation at home or at school. *How much radiation are humans exposed to in daily life, and what risks and benefits are involved?*

Acquisition and Development of Concepts

- Students can recognize, through the use of appropriate radiation detectors, that low-level radioactivity can occur in their environment (for example, smoke detectors use a small radioactive source, radon gas can seep into basements).
- Students use print and electronic resources to locate and summarize information such as common sources of radiation and half-lives of isotopes, and exposure levels of radiation per annum. They then determine their own radiation exposure levels.
- Students compare the causes of death from radiation with other causes of death, such as traffic accidents and smoking, and with deaths that occur in certain occupations and recreational activities.

Application

- Students complete a risk-benefit analysis of exposure to artificial sources of radiation or to sources used for biomedical diagnoses and treatments such as radioactive tracers and cobalt therapies.

Illustrative Example 4:

Analyze interactions within systems, using the laws of conservation of energy and momentum.

Bungee jumping has become popular with thrill seekers throughout the world. Designing bungee ropes and determining a safe height for the platform are important considerations in reducing risk. Students should be able to apply the conservation laws of energy and momentum when analyzing situations such as bungee jumping.

Suggestions for Instruction

Activating Prior Knowledge

- Students view, either directly or on video, the sport of bungee jumping and note the sequence of events during a jump. After viewing the video, they examine and note the properties of a bungee rope. *How can you redesign an existing bungee jump to accommodate jumpers of masses between 35 kg and 120 kg?*

Acquisition and Development of Concepts

- Students use the law of conservation of energy to determine the velocity a person would have at the end of the initial bungee jump.
- Students develop a design for a laboratory scale prototype of a bungee jump that can accommodate a range of masses. Students build and test the bungee jump prototype using a variety of masses, and make adjustments as necessary. Students compare theoretical data with data collected from prototype tests.

Application

- Students extrapolate findings from prototype tests to actual conditions, taking into consideration aspects such as the mass of the jumper, the height of the jump platform, free-fall distance, spring constant, potential and kinetic energies, using numerical and graphical modes of representation.
- Students identify tradeoffs in the design of a bungee jump (for example, thrill element versus safety precautions).

Illustrative Example 5:

Demonstrate an understanding of the nature and diversity of energy sources and matter in the universe.

Many of Earth's resources are nonrenewable. In recent years, humans have become more aware of the need to recover and use resources in a responsible way. Students should develop an understanding and appreciation of the finite nature of Earth's resources and how these resources should be used to meet both present needs and the needs of future generations.

Activating Prior Knowledge

- Through discussion or a brainstorming session, students indicate their understanding of the significance of mining or logging activities in a global context and the contribution of mining activities to the local, provincial, or national economy. *What types of information are necessary and what processes are used to make a decision about whether a specific mining activity should proceed?*

Acquisition and Development of Concepts

- Students analyze seismic data and drill-core sample data to determine the nature and size of a particular ore body. Students further analyze social, economic, and environmental factors to determine the economic viability or feasibility of developing the ore body, and to make and justify a decision.
- Students role-play or debate the question of developing a mineral resource that has been discovered in a protected area. As a group, students could reach a consensus as to whether or not the resource should be developed.

Application

- Students role-play as investors and apply their knowledge to the interpretation of a mining company prospectus.
- Students hold a town hall meeting to discuss this scenario: The local mine has just shut down and eliminated many jobs. A logging company would like to clear-cut a local forest.