Grades 5 to 8
Manitoba Foundations
for Scientific Literacy

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The Five Foundations

To develop scientifically literate students, science learning experiences must incorporate the essential aspects of science and related applications. These essential aspects, the foundations for scientific literacy, have been adapted from the *Pan-Canadian Science Framework* to address the needs of Manitoba students. Manitoba science curricula are built upon the following five foundations for scientific literacy:

A. Nature of Science and Technology

B. Science, Technology, Society, and the Environment (STSE)

C. Scientific and Technological Skills and Attitudes

D. Essential Science Knowledge

E. Unifying Concepts

> Producing science knowledge is an intrinsically collective endeavour. There is no such thing as stand-alone science. Scientists submit models and solutions to the assessment of their peers who judge their logical and experimental soundness by reference to the body of existing knowledge.
> (*Larochelle, M. and J. Désautels,* 1992)

In the following pages each foundation is described and accompanied by general learning outcomes, which further define expectations for student learning. These general learning outcomes constitute a global picture of science learning from Kindergarten to Senior 4.

A. Nature of Science and Technology

Students must learn that science and technology are creative human activities with long histories in all cultures of the world.

Science is a way of learning about the universe. This learning stems from curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over the evidence and its interpretations. Scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science argue that there is no set procedure for conducting a scientific investigation. Rather, they see science as driven by a combination of theories, knowledge, experiments, and processes anchored in the physical world.

Scientific theories are being tested, modified, and refined continuously as new knowledge and theories supersede existing ones. Scientific debate on new observations and hypotheses that challenge accepted knowledge involves many participants with diverse backgrounds. This highly complex interplay, which has occurred throughout history, is fuelled by theoretical discussions, experimentation, social, cultural, economic, and political influences, personal biases, and the need for peer recognition and acceptance. Students will realize that while some of our understandings about how the world works are due to revolutionary scientific developments, many of our understandings result from the steady and gradual accumulation of knowledge.

Technology is concerned mainly with proposing solutions to problems arising from attempts by humans to adapt to the environment. Technology may be regarded as ". . . a tool or machine; a process, system, environment, epistemology, and ethic; the systematic application of knowledge, materials, tools, and skills to extend human capabilities. . . ." (*Technology As a Foundation Skill Area: A Journey Toward Information Technology Literacy*, 1998). Technology includes much more than the knowledge and skills related to computers and their applications. Technology is both a form of knowledge that uses concepts and skills from other disciplines (including science) and the application of this knowledge to meet an identified need or solve a problem using materials, energy, and tools (including computers). Technology also has an impact on processes and systems, on society, and on the ways people think, perceive, and define their world.

This *Science Framework* is designed to emphasize both the distinctions and relationships between science and technology. Figure 1 illustrates how science and technology differ in purpose, procedure, and product, while, at the same time, interacting with each other.

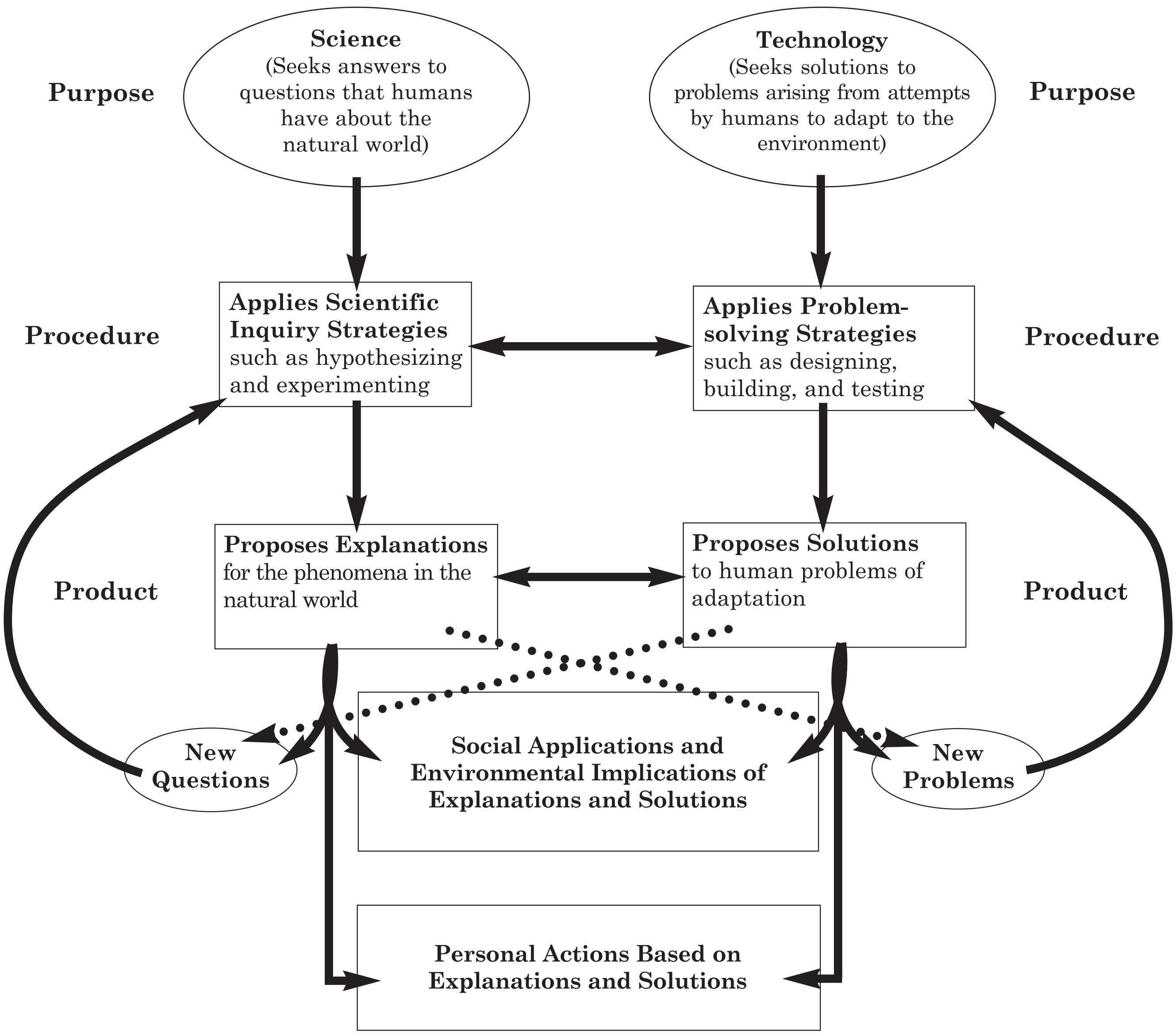

Figure 1: Science and Technology: Their Nature and Relationship

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Adapted with permission from Bybee, Rodger W. *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction.* ©The NETWORK, Inc.

The following general learning outcomes (GLOs) have been developed to further define expectations related to this foundation area. (For a complete listing of science GLOs, see Appendix 1.)

Nature of Science and Technology General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will...

A1. recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena

A2. recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop

A3. distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values

A4. identify and appreciate contributions made by women and men from many societies and cultural backgrounds towards increasing our understanding of the world and in bringing about technological innovations

A5. recognize that science and technology interact with and advance one another

B. Science, Technology, Society, and the Environment (STSE)

STSE understandings are an essential component of scientific literacy. By studying the historical context, students come to appreciate ways in which cultural and intellectual traditions have influenced the questions and methodologies of science, and how science, in turn, has influenced the wider world of ideas.

Today, most scientists work in industry, where projects are more often driven by societal and environmental needs than by pure research. Many technological solutions have evoked complex social and environmental issues. Students, as future citizens, must recognize the potential of scientific literacy to inform and empower decision making of individuals, communities, and democratic society as a whole.

> There can be no greater contribution or more essential element to long-term environmental strategies leading to sustainable development that respects the environment…than the education of future generations in matters relating to the environment. (*UNESCO,* 1988)

Scientific knowledge is necessary, but is not in itself sufficient for understanding the relationships among science, technology, society, and the environment. To understand these relationships, it is essential that students understand the values related to science, technology, society, and the environment.

To achieve scientific literacy, students must develop an appreciation for the importance of sustainable development. To this end, this *Science Framework* integrates the Sustainable Development Strategy developed by the Province of Manitoba (see Figure 2).

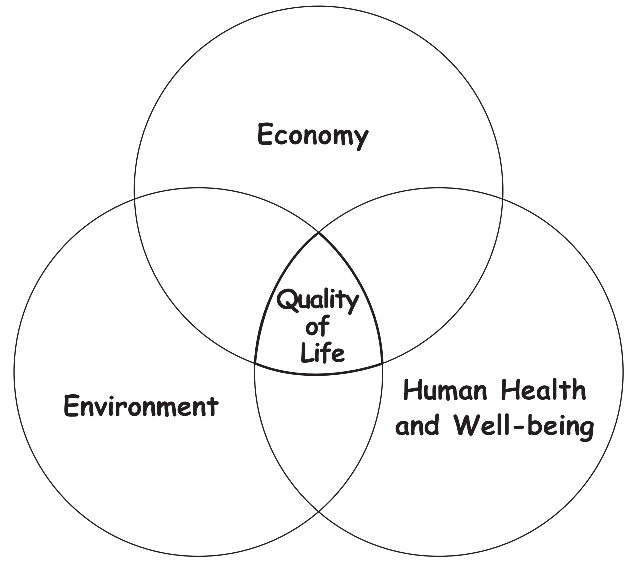

Figure 2: Sustainable Development

Sustainable development is a decision-making model that considers the needs of both present and future generations, and integrates and balances the **impact of economic activities**, the **environment**, and the **health and well-being of the community**.

> Public awareness and understanding of the concept of sustainable development and its practices are essential. If we are to change our way of life we must equip present and future generations with the knowledge and training to put sustainable development into effect. (*Sustainable Development Strategy for Manitoba,* 1994)

As students advance from grade to grade, they identify STSE interrelationships and apply decision-making skills in increasingly demanding contexts, as shown below:

- **complexity of understanding** — from simple, concrete ideas to abstract ideas; from limited knowledge of science to more in-depth and broader knowledge of science and the world
- **applications in context** — from contexts that are local and personal to those that are societal and global
- **consideration of variables and perspectives** — from one or two that are simple to many that are complex
- **critical judgement** — from simple right or wrong assessments to complex evaluations
- **decision making** — from decisions based on limited knowledge, made with the teacher's guidance, to decisions based on extensive research, involving personal judgement and made independently

The following general learning outcomes (GLOs) have been developed to further define expectations related to this foundation area. (For a complete listing of Manitoba's science GLOs see Appendix 1.)

Science, Technology, Society, and the Environment (STSE) General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will...

B1. describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally

B2. recognize that scientific and technological endeavours have been and continue to be influenced by human needs and the societal context of the time

B3. identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social

B4. demonstrate a knowledge of and personal consideration for a range of possible science- and technology- related interests, hobbies, and careers

B5. identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally

C. Scientific and Technological Skills and Attitudes

A science education that strives for scientific literacy must engage students in answering questions, solving problems, and making decisions. These processes are referred to as Scientific Inquiry, Technological Problem Solving (Design Process), and Decision Making (see Figure 3: Processes for Science Education). While the skills and attitudes involved in these processes are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations.

Each of these processes is described on the following page. Attitudes, an important element of each process, are also examined.

	Scientific Inquiry	**Technological Problem Solving (Design Process)**	**Decision Making**
Purpose:	Satisfying curiosity about events and phenomena in the natural world.	Coping with everyday life, practices, and human needs.	Identifying different views or perspectives based on different or the same information.
Procedure:	What do we know? What do we want to know?	How can we do it? Will it work?	What alternatives or consequences are there? Which choice is best at this time?
Product:	Knowledge about events and phenomena in the natural world.	An effective and efficient way to accomplish a task or meet a need.	A defensible decision in the particular circumstances.

	Scientific Question	**Technological Problem**	**STSE Issue**
Example:	Why does my coffee cool so quickly? *An Answer:* Heat energy is transferred by conduction, convection, and radiation.	How can I keep my coffee hot? *A Solution:* A styrofoam cup will keep liquids warm for a long time.	Should we use styrofoam cups or ceramic mugs for our meeting? *A Decision:* Personal health, the environment, cost, and availability must be considered along with science and technology information.

Figure 3: Processes for Science Education

Adapted with permission of the Minister of Learning, Province of Alberta, Canada, 1999.

Scientific Inquiry

Scientific inquiry is a way of learning about the universe. It involves posing questions and searching for explanations of phenomena. Although no single "scientific method" exists, students require certain skills to participate in science-related experiences.

Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, planning experiments, collecting, analyzing, and interpreting data are fundamental to scientific inquiry; as are attitudes such as curiosity, skepticism, and creativity. These skills are often represented as a cycle. This cycle involves posing questions, generating possible explanations, and collecting and analyzing evidence to determine which of these explanations is most useful and accurate in accounting for the phenomena under investigation. New questions may arise to re-ignite the cycle. It must be noted, however, that many scientific inquiries, past and present, do not necessarily follow a set sequence of steps nor do they always start at the "beginning" of the cycle: scientists can be creative and responsive to scientific challenges as they arise.

Technological Problem Solving (Design Process)

Technological problem solving seeks solutions to problems arising from attempts by humans to adapt to the environment. Related skills and attitudes are often represented as a cycle, referred to as the **design process**. The design process includes proposing, creating, and testing of prototypes, and the evaluation of consumer products and techniques in an attempt to reach an optimal solution to a given problem. Feedback and evaluation are built into this cycle, which, like scientific inquiry, can be an ongoing set of revisited steps. However, technological problem solving and scientific inquiry differ in purpose, procedure, and product (see Figure 1: Science and Technology: Their Nature and Relationship, p. 2.5).

Decision Making

Students, as individuals and global citizens, are required to make decisions, and increasingly, the types of issues they face demand an ability to apply scientific and technological processes and products. The decision-making process involves identifying the issue, gathering data, generating possible courses of action, evaluating alternatives, and making a thoughtful decision based on the information available. Students should be actively involved in decision-making situations as they progress through their science education. Not only are decision-making situations important in their own right, but they also provide a relevant context for engaging in scientific inquiry, problem solving, and the study of STSE relationships.

Attitudes

Attitudes refer to generalized aspects of behaviour that are modelled for students and reinforced by selective approval. Attitudes are not acquired in the same way as skills and knowledge. They cannot be observed at any particular moment, but are evidenced by regular, unprompted manifestations over time. Development of attitudes is a lifelong process that involves the home, the school, the community, and society at large. The development of positive attitudes plays an important role in students' growth by interacting with their intellectual development and by creating a readiness for responsible application of what they learn.

The following General Learning Outcomes (GLOs) have been developed to further define expectations related to this foundation area. (For a complete listing of Manitoba's science GLOs, see Appendix 1).

Scientific and Technological Skills and Attitudes General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will...

C1. recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations

C2. demonstrate appropriate scientific inquiry skills when seeking answers to questions

C3. demonstrate appropriate problem-solving skills while seeking solutions to technological challenges

C4. demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information

C5. demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind

C6. employ effective communication skills and utilize information technology to gather and share scientific and technological ideas and data

C7. work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities

C8. evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life

D. Essential Science Knowledge

The subject matter of science includes theories, models, concepts, and principles that are essential to an understanding of life science, physical science, and Earth and space science. While this *Science Framework* is not strictly aligned with these disciplines, the learning outcomes are intended to help develop important concepts from each of these areas.

Life science deals with the growth and interactions of life forms within their environment in ways that reflect their uniqueness, diversity, genetic continuity, and changing nature. Life science includes the study of organisms (including humans), ecosystems, biodiversity, cells, biochemistry, and biotechnology.

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

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

The following General Learning Outcomes (GLOs) have been developed to further define expectations related to this foundation area. (For a complete listing of Manitoba's science GLOs, see Appendix 1.)

Essential Science Knowledge General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will...

D1. understand essential life structures and processes pertaining to a wide variety of organisms, including humans

D2. understand various biotic and abiotic components of ecosystems, as well as their interaction and interdependence within ecosystems and within the biosphere as a whole

D3. understand the properties and structures of matter as well as various common manifestations and applications of the actions and interactions of matter

D4. understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts

D5. understand the composition of the Earth's atmosphere, hydrosphere, and lithosphere, as well as the processes involved within and among them

D6. understand the composition of the universe, the interactions within it, and the impacts of humankind's continued attempts to understand and explore it

E. Unifying Concepts

An effective way to create linkages within and among science disciplines is to use unifying concepts; these are key ideas that underlie and integrate all science knowledge and extend into areas such as mathematics and social studies. Consequently, unifying concepts help students to construct a holistic understanding of science and its role in society. The following four unifying concepts were used in the development of this *Science Framework*.

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, organisms, and events that help to make useful distinctions between and among them. Over time, students adopt accepted procedures and protocols for describing and classifying objects, organisms, and events they encounter, thus enabling them to share ideas with others and to reflect on their own experiences.

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 often greater than that of the individual parts, even when these are considered together. Students will study both natural and technological systems.

Change, Constancy, and Equilibrium

The concepts of constancy and change underlie most understandings of the natural and technological world. Through observations, students learn that some characteristics of living things, materials, and systems remain constant over time, whereas others change. Through formal and informal studies, students develop an understanding of the processes and conditions in which change, constancy, and equilibrium take place.

Energy

Energy, as a concept, provides a conceptual tool that brings together many understandings about natural phenomena, materials, and the processes 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 the interactions of materials, the processes of life, and the functioning of systems.

The following General Learning Outcomes (GLOs) have been developed to further define expectations related to this foundation area. (For a complete listing of Manitoba's science GLOs see Appendix 1.)

Unifying Concepts General Learning Outcomes

As a result of their Early, Middle, and Senior Years science education, students will...

E1. describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world

E2. describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems

E3. recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved

E4. recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them

Conceptual Organizer

The following conceptual organizer (see Figure 4) summarizes the relationships among the Manitoba Foundations for Scientific Literacy and shows how they are translated into general and specific student learning outcomes at Kindergarten to Senior 4.

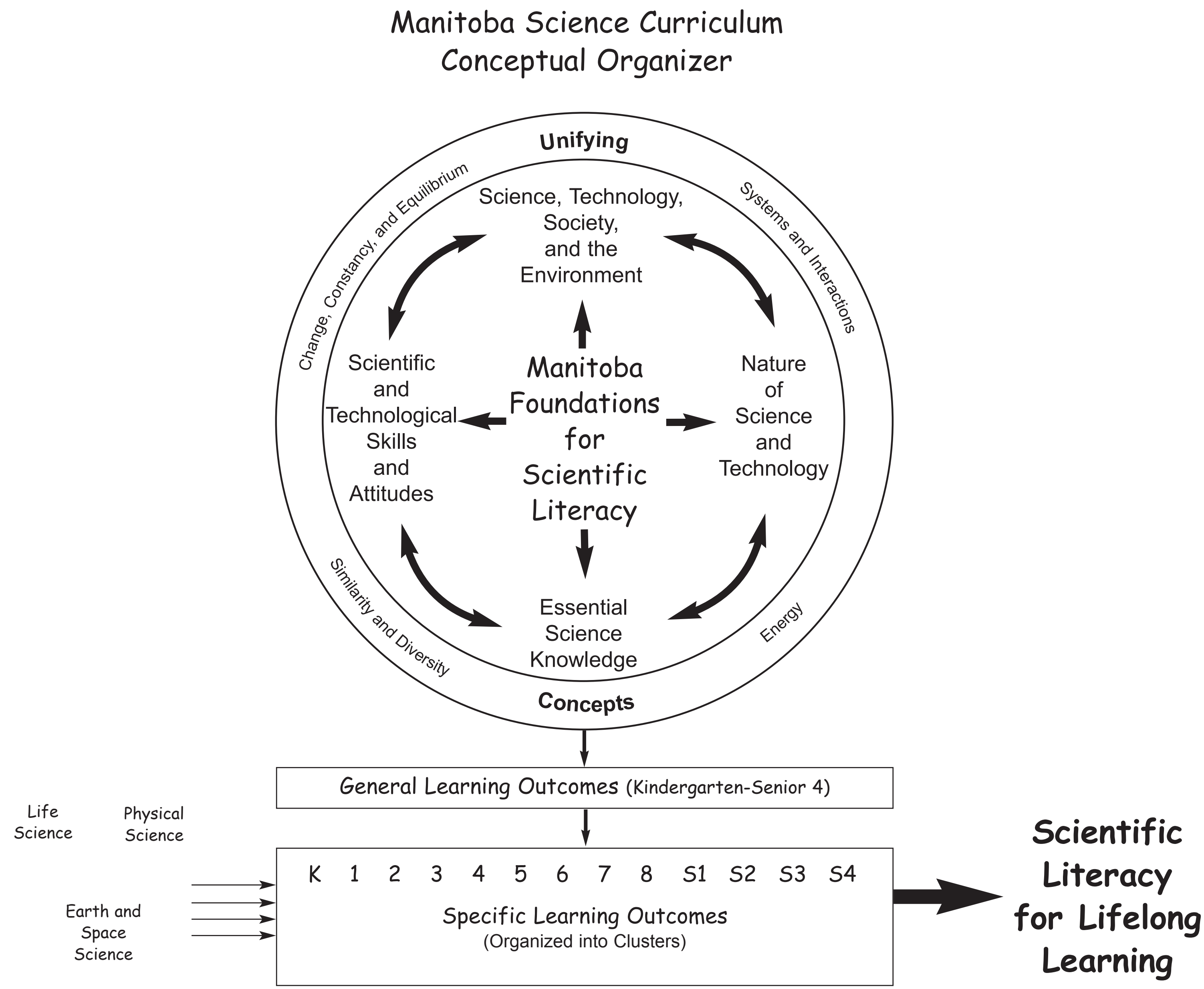

Figure 4: Manitoba Science Curriculum Conceptual Organizer

Notes